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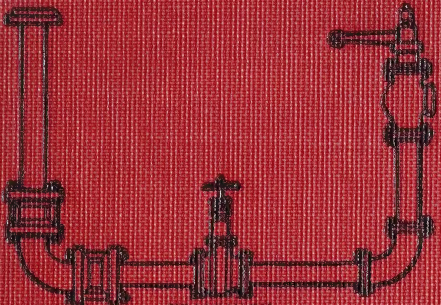
ON
HEATING VENTILATING
AND
MECHANICAL REFRIGERATION



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A PRACTICAL BOOK
FOR PRACTICAL MEN

G. Cooke.

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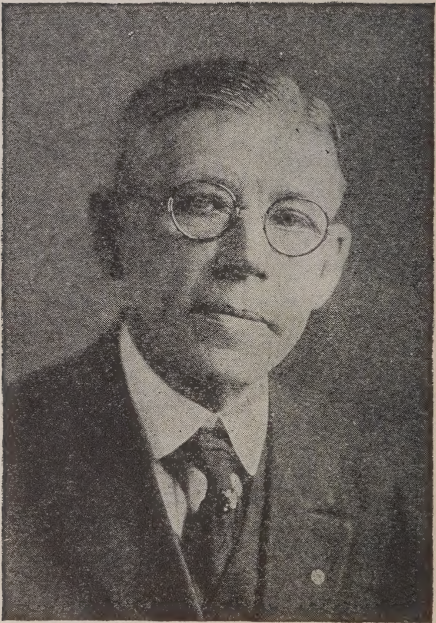

JOHN W. JOHNSON,

Author and Publisher of "Johnson's Handy Manual"
and Mechanical Engineer

JOHNSON'S NEW HANDY MANUAL

ON

HEATING VENTILATING AND MECHANICAL REFRIGERATION

TWELFTH EDITION

PRICE by Parcel Post $1.50 Net
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JOHN W. JOHNSON

PARK RIDGE, ILL.
U. S. A.

REGISTERED PROFESSIONAL ENGINEER
MECHANICAL
G. R. COOKE
PROVINCE OF ONTARIO

Dedication

TO THE STEAM-FITTERS AND PLUMBERS

WITH WHOM I HAVE SPENT
SO MANY PLEASANT YEARS,
I DEDICATE THIS MANUAL

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451

Johnson's Handy Manual.

Cross-Connected Pumps

Fig. A shows a battery of boilers with cross-connected pumps. Feed water heater and tank on the roof.

The installation is as follows:

For Suction:

Connect pumps No. 1 and No. 2, as in illustration, by 4"x3" tees to the city main. Between the tees and pump connections insert gate valves A and B and flange unions. Valve must in all cases be next to the tee so that in case either pump should have to be disconnected, valves A or B can be closed and the pump disconnected without interfering with the water supply.

From the tee, connecting pump No. 1, run a 4" pipe to a point directly under the roof tank and with a long sweep elbow continue the pipe up through the roof and connect to the bottom of the tank on this pipe, marked 4" tank suction on the illustration, at a convenient place, insert a 4x2" tee and connect with 2" pipe, marked "feed to boiler through heater," using valve C and flange union. When feed from tank direct to boilers close valve D and open valve C. When feed which has passed through the heater is wanted close valve C and open valve D. Check valve E. E. must be set to open with the flow of water from tank or heater.

Pump Discharge:

When pumping to roof tank close valves F. and G. and open valves H. and I. Check valve J. must be set to open with the flow of water to the tank.

If direct feed from pump No. 1 to boiler is wanted proceed as follows:

Close valves H., G. and L. and open valves F. and M. The flow will open check valve E and close check valve E. E. If direct feed from Pump No. 2 to boiler is wanted close valves I., F. and L. and open valves G. and M. Check valves E. and E. E. have the same action as when pump No. 1 is used.

Feed to Heater:

When using pump No. 1 to supply water to heater, close valves H., G. and M. and open valves F. and L. When pump No. 2 is used close valves I., F. and M. and open valves G. and L.

Note:

Illustration being an elevation to show all pipes, valves and unions, the position of the pipes must necessarily be somewhat extorted.

Pipes should not be higher from the floor but what a man could easily reach all valves when standing on the floor.

All valves on branches should be placed as near as possible to the supply pipe from which its duty is to stop the supply when not wanted; for instance: Valves, H. and I. with their unions should be placed as near the tees N. and O. as possible.

Steam to pumps, exhaust from pumps to heater and feed to boiler through heater are shown so plainly in the illustration that any explanation is unnecessary.

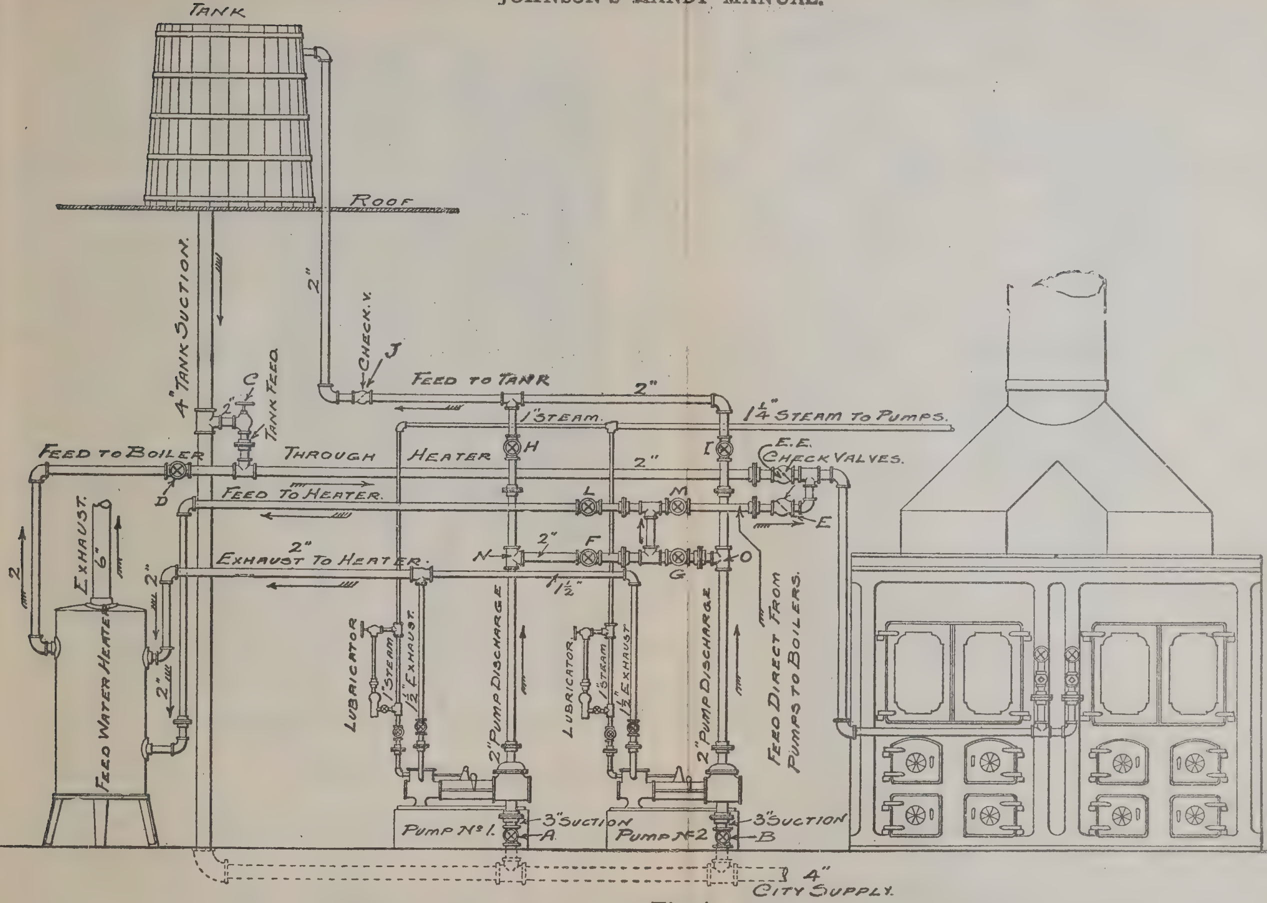
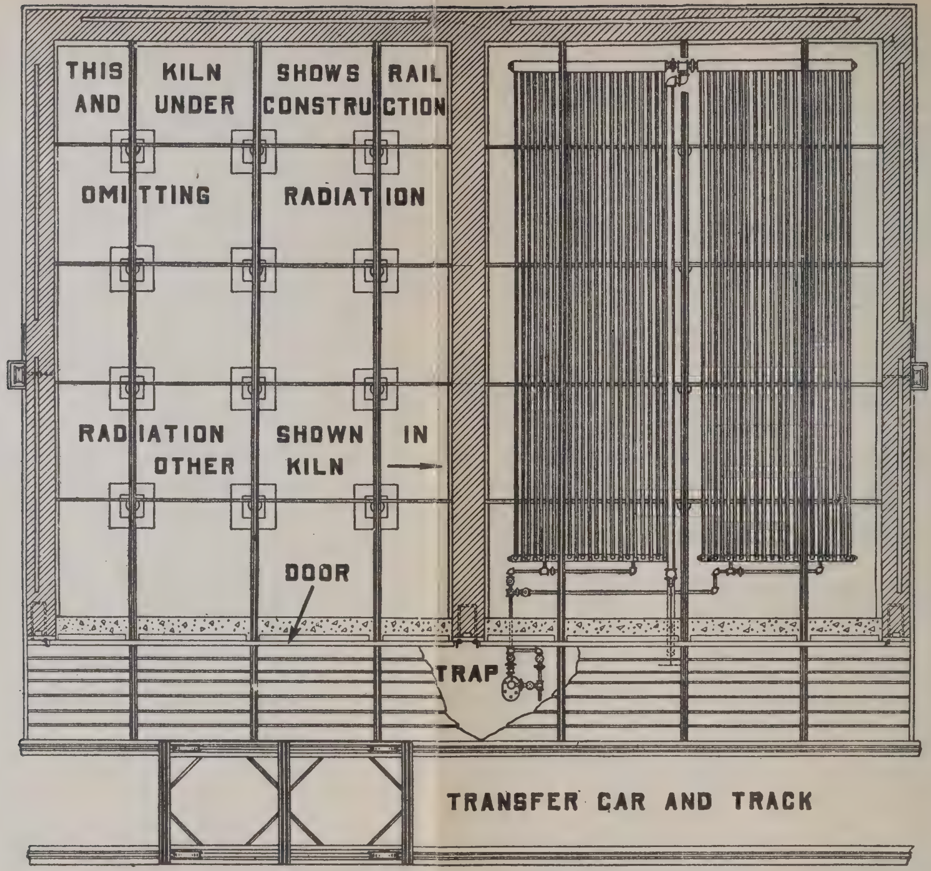

TANK
ROOF
4" TANK SUCTION.
2"
CHECK.V.
J
C
2"
TANK FEED.
FEED TO TANK
2"
1¼" STEAM TO PUMPS.
1" STEAM.
FEED TO BOILER
THROUGH
HEATER
H
I
2"
E.E. CHECK VALVES.
D
FEED TO HEATER.
L
M
E
EXHAUST.
6"
2
2"
N
2"
F
G
O
EXHAUST TO HEATER.
1½"
FEED WATER HEATER
2"
LUBRICATOR
1" STEAM
1½" EXHAUST
2" PUMP DISCHARGE
LUBRICATOR
1" STEAM
1½" EXHAUST
2" PUMP DISCHARGE
FEED DIRECT FROM PUMPS TO BOILERS.
3" SUCTION
PUMP Nº 1.
A
3" SUCTION
PUMP Nº 2
B
4"
CITY SUPPLY.

Fig. A



THIS KILN SHOWS RAIL AND UNDER CONSTRUCTION
OMITTING RADIATION
RADIATION SHOWN IN OTHER KILN
DOOR
TRAP
TRANSFER CAR AND TRACK

PLAN OF PAIR OF MODERN BOX DRY KILNS FOR LUMBER EACH TO BE APPROXIMATELY 16-FT WIDE BY 27-FT LONG 10-FT HIGH INSIDE AND ABOVE RAIL. WILL EACH HOLD APPROXIMATELY 15000 FEET BOARD MEASURE (AN AVERAGE RAILROAD CAR) OF ONE INCH LUMBER 16-FT LONG. TO BE ERECTED OF BRICK WITH AIR SPACE IN WALL, CONCRETE FOUNDATIONS, TILE ROOF, WOOD DOORS AND PLATFORMS.

COURTESY OF GRAND RAPIDS DRY KILN

An Easy and Correct Method of Ascertaining Length of Pipe Required in 45° Angles

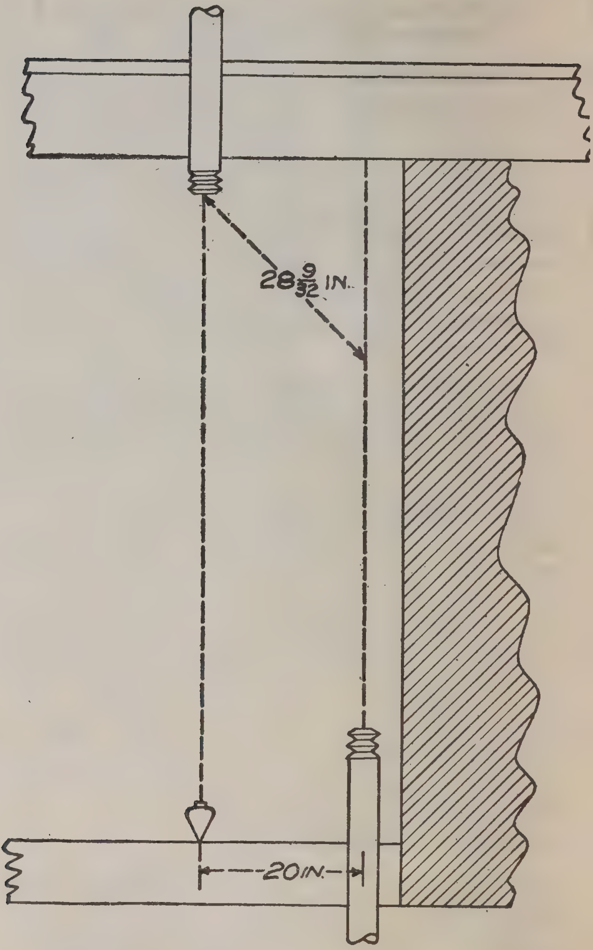
In the pipe fitting of steam and hot water heating plants, 45 degree elbows are brought into use extensively and it is not every mechanic who has mastered mathematics sufficiently to be able to figure square root in order to find the hypotenuse of an angle, and on this account we give the following methods of getting the measurements of 45 degree angles, which is approximately correct for pipe use.

For each inch of offset add $^{53}/_{128}$ of an inch and the result will be the distance from center to center of the 45 degree angle.

For instance: Referring to illustration, Fig 4, we will suppose that a pipe is to be brought up from a lower floor near a wall, and it is to pass through the ceiling of a room at a distance of 20 inches farther away from the wall than that which it rises through the floor, as indicated in the illustration by the figures, 20 inches, which is shown by the plumb-bob. This shows that the distance in a straight line from center to center of the two points is 20 inches. Now it is simply necessary to add to the 20 inches 20 times 53, and divide the result by 128, to get the additional length necessary for the 45 degree angle. Thus:—$20 \times 53 = 1060$, $1060 \div 128 = 8^{9}/_{32}$, which added to the 20 inches, makes the distance of the angle, as shown, $28^{9}/_{32}$ inch.

In any case it will be necessary to allow for the distance taken up by the fittings from center to center of same, as shown in Fig. 5.

By this system it will make no difference how many inches the offset may be; simply add for each inch an additional fraction of $^{53}/_{128}$ of an inch. Again, suppose the offset is to be 5 inches, we multiply 5


28 9/32 IN.
20 IN.

by 53, which gives us 265. We now divide the 265 by 128, which gives us 2¹/₁₆; this result we now add to 5 inches, which is the distance of offset, and we have 7¹/₁₆ inches from center to center of the 45 degree angle. Any distance may be obtained in the same manner.

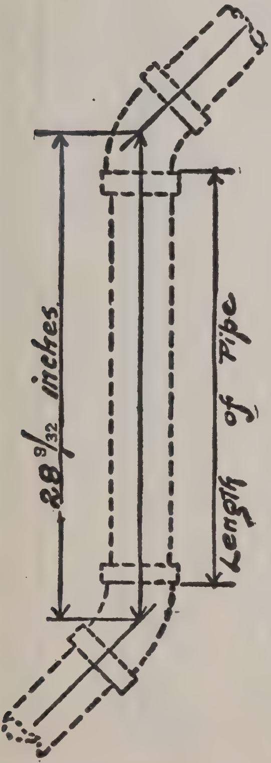


Fig. 5

Table of Diagonals for 45° Triangles Measuring from 1 Inch to 20 Feet on the Sides.

Sides. Ft.	Sides. In.	Diagonal. Ft.	Diagonal. In.	Sides. Ft.	Sides. In.	Diagonal. Ft.	Diagonal. In.
	1		1 7/16	3	1	4	4 5/16
	2		2 13/16	3	2	4	5 3/4
	3		4 1/4	3	3	4	7 3/16
	4		5 5/8	3	4	4	8 9/16
	5		7 1/16	3	5	4	10
	6		8 1/2	3	6	4	11 3/8
	7		9 7/8	3	7	5	13/16
	8		11 5/16	3	8	5	2 1/4
	9		12 3/4	3	9	5	3 5/8
	10	1	2 1/8	3	10	5	5 1/16
	11	1	3 9/16	3	11	5	6 7/16
	12	1	5	4		5	7 7/8
1	1	1	6 3/8	4	1	5	9 5/16
1	2	1	7 13/16	4	2	5	10 11/16
1	3	1	9 3/16	4	3	6	1/8
1	4	1	10 5/8	4	4	6	1 9/16
1	5	2	1/16	4	5	6	2 15/16
1	6	2	1 7/16	4	6	6	4 3/8
1	7	2	2 7/8	4	7	6	5 3/4
1	8	2	4 5/16	4	8	6	7 3/16
1	9	2	5 11/16	4	9	6	8 5/8
1	10	2	7 1/8	4	10	6	10
1	11	2	8 1/2	4	11	6	11 7/16
2		2	9 15/16	5		7	7/8
2	1	2	11 3/8	5	1	7	2 1/4
2	2	3	3/4	5	2	7	3 11/16
2	3	3	2 3/16	5	3	7	5 1/16
2	4	3	3 5/16	5	4	7	6 1/2
2	5	3	5	5	5	7	7 15/16
2	6	3	6 7/16	5	6	7	9 5/16
2	7	3	7 13/16	5	7	7	10 3/4
2	8	3	9 1/4	5	8	8	3/16
2	9	3	10 11/16	5	9	8	1 9/16
2	10	4	1/16	5	10	8	3
2	11	4	1 1/2	5	11	8	4 7/16
3		4	2 15/16	6		8	5 13/16

Extreme caution must be exercised in taking off centers of fittings in these measurements.

Table of Diagonals for 45° Triangles Measuring from 1 Inch to 20 Feet on the Sides.

Sides.		Diagonal.		Sides.		Diagonal.	
Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.
6	1	8	7¼	9	1	12	10⅛
6	2	8	8⅝	9	2	12	11 9/16
6	3	8	10 1/16	9	3	13	1
6	4	8	11½	9	4	13	2⅜
6	5	9	⅞	9	5	13	3 13/16
6	6	9	2 5/16	9	6	13	5¼
6	7	9	3¾	9	7	13	6⅝
6	8	9	5⅛	9	8	13	8 1/16
6	9	9	6½	9	9	13	9 7/16
6	10	9	7 15/16	9	10	13	10⅞
6	11	9	9⅜	9	11	14	5/16
7		9	10 13/16	10		14	1 11/16
7	1	10	3/16	10	1	14	3⅛
7	2	10	1⅝	10	2	14	4 9/16
7	3	10	3	10	3	14	5 15/16
7	4	10	4 7/16	10	4	14	7⅜
7	5	10	5⅞	10	5	14	8¾
7	6	10	7¼	10	6	14	10 3/16
7	7	10	8 11/16	10	7	14	11⅝
7	8	10	10⅛	10	8	15	1
7	9	10	11½	10	9	15	2 7/16
7	10	11	15/16	10	10	15	3⅞
7	11	11	2⅜	10	11	15	5¼
8		11	3¾	11		15	6 11/16
8	1	11	5 3/16	11	1	15	8 1/16
8	2	11	6⅝	11	2	15	9½
8	3	11	8	11	3	15	10 15/16
8	4	11	9 7/16	11	4	16	⅜
8	5	11	10 13/16	11	5	16	1¾
8	6	12	¼	11	6	16	3 3/16
8	7	12	1 11/16	11	7	16	4 9/16
8	8	12	3 1/16	11	8	16	6
8	9	12	4½	11	9	16	7⅜
8	10	12	5⅞	11	10	16	8 13/16
8	11	12	7 5/16	11	11	16	10¼
9		12	8¾	12		16	11⅝

Extreme caution must be exercised in taking off centers of fittings in these measurements.

Table of Diagonals for 45° Triangles Measuring from 1 Inch to 20 Feet on the Sides.

Sides.		Diagonal.		Sides.		Diagonal.	
Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.
12	1	17	1 1/16	15	1	21	4
12	2	17	2 7/16	15	2	21	5 3/8
12	3	17	3 7/8	15	3	21	6 13/16
12	4	17	5 5/16	15	4	21	8 3/16
12	5	17	6 11/16	15	5	21	9 5/8
12	6	17	8 1/8	15	6	21	11 1/16
12	7	17	9 9/16	15	7	22	7/16
12	8	17	10 15/16	15	8	22	1 7/8
12	9	18	3/8	15	9	22	3 5/16
12	10	18	11 13/16	15	10	22	4 11/16
12	11	18	3 3/16	15	11	22	6 1/8
13		18	4 5/8	16		22	7 1/2
13	1	18	6	16	1	22	8 15/16
13	2	18	7 7/16	16	2	22	10 3/8
13	3	18	8 7/8	16	3	22	11 3/4
13	4	18	10 1/4	16	4	23	1 3/16
13	5	18	1 11/16	16	5	23	2 5/8
13	6	19	1 1/8	16	6	23	4
13	7	19	2 1/2	16	7	23	5 7/16
13	8	19	3 15/16	16	8	23	6 13/16
13	9	19	5 5/16	16	9	23	8 1/4
13	10	19	6 3/4	16	10	23	9 11/16
13	11	19	8 3/16	16	11	23	11 1/16
14		19	9 9/16	17		24	1/2
14	1	19	11	17	1	24	1 15/16
14	2	20	7/16	17	2	24	3 5/16
14	3	20	1 13/16	17	3	24	4 3/4
14	4	20	3 1/4	17	4	24	6 1/8
14	5	20	4 11/16	17	5	24	7 9/16
14	6	20	6 1/16	17	6	24	9
14	7	20	7 1/2	17	7	24	10 3/8
14	8	20	8 7/8	17	8	24	11 13/16
14	9	20	10 5/16	17	9	25	1 1/4
14	10	20	11 3/4	17	10	25	2 5/8
14	11	21	1 1/8	17	11	25	4 1/16
15		21	2 9/16	18		25	5 1/2

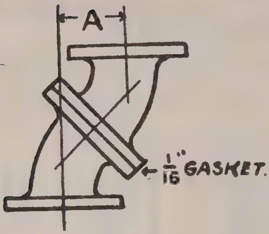
Extreme caution must be exercised in taking off centers of fittings in these measurements.

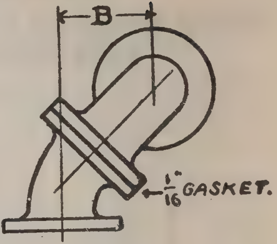
Table of Diagonals for 45° Triangles Measuring from 1 Inch to 20 Feet on the Sides.

Sides.		Diagonal.		Sides.		Diagonal.	
Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.
18	1	25	6⅞	19	1	26	11⅞
18	2	25	8 5/16	19	2	27	1¼
18	3	25	9 11/16	19	3	27	2 11/16
18	4	25	11⅛	19	4	27	4 1/16
18	5	26	9/16	19	5	27	5½
18	6	26	1 15/16	19	6	27	6 15/16
18	7	26	3⅜	19	7	27	8 5/16
18	8	26	4 13/16	19	8	27	9¾
18	9	26	6 3/16	19	9	27	11 3/16
18	10	26	7⅝	19	10	28	9/16
18	11	26	9	19	11	28	2
19		26	10 7/16	20		28	3 7/16

Extreme caution must be exercised in taking off centers of fittings in these measurements.

OFFSETS
STANDARD FLGD. ELLS.





45° ELLS

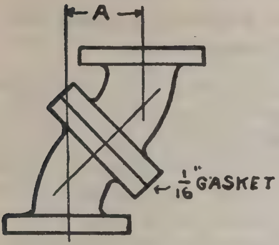
SIZE	OFFSET A
2	3 9/16
2 1/2	4 1/4
3	4 1/4
3 1/2	5
4	5 11/16
4 1/2	5 11/16
5	6 3/8
6	7 1/8
7	7 13/16
8	7 13/16
9	8 1/2
10	9 1/4
12	10 5/8
14	10 5/8
15	11 3/8
16	11 3/8
18	12 1/16
20	13 1/2
22	14 3/16
24	15 5/8

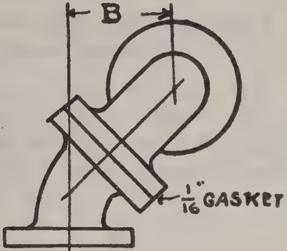
45° AND 90° ELLS.

SIZE	OFFSET B
2	5
2 1/2	5 11/16
3	6 1/16
3 1/2	6 3/4
4	7 7/16
4 1/2	7 13/16
5	8 1/2
6	9 1/4
7	9 15/16
8	10 7/16
9	11 3/8
10	12 7/16
12	13 13/16
14	15 1/4
15	15 15/16
16	16 5/16
18	17 11/16
20	19 1/2
22	21 1/4
24	23 3/8

OFFSETS.

EXTRA HEAVY FLGD. ELLS.





45° ELLS

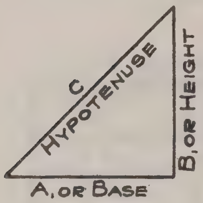
SIZE	OFFSET A
2	4 1/4
2 1/2	5
3	5
3 1/2	5 11/16
4	6 3/8
4 1/2	6 5/8
5	7 1/8
6	7 13/16
7	8 1/2
8	8 1/2
9	9 1/4
10	9 15/16
12	11 3/8
14	11 3/8
15	12 1/16
16	12 3/4
18	13 1/2
20	14 3/16
22	14 7/8
24	16 5/16

45° AND 90° ELLS

SIZE	OFFSET B
2	5 11/16
2 1/2	6 3/8
3	6 3/4
3 1/2	7 7/16
4	8 3/16
4 1/2	8 1/2
5	9 1/4
6	9 15/16
7	10 5/8
8	11 3/8
9	12 1/16
10	13 1/8
12	14 7/8
14	15 15/16
15	16 5/8
16	17 11/16
18	18 3/4
20	20 3/16
22	21 5/8
24	23 3/4

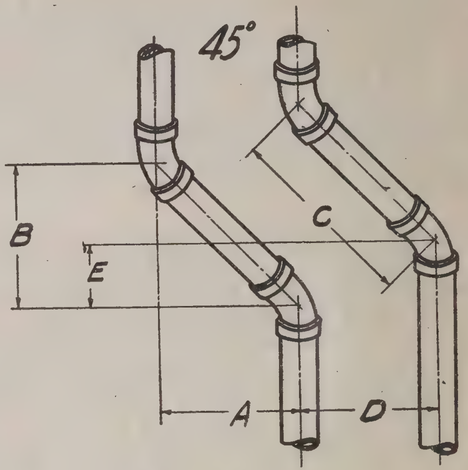
Instructions for Using the Following Formula for Figuring Angle Measurements

All common angles can be compared to a right angle triangle. "A" represents the BASE, "B" the HEIGHT, and "C" the HYPOTENUSE. "A" or the base is the offset or the first measurement taken and (is at right angles from the run of pipe) from "A" or the base the other measurements must be figured. For example, in running a line of pipe and making a 12″ offset, using 60° fittings, referring to the formula for figuring 60° fittings, you have "A" measurement and have to figure "B" and "C" from "A," glance down the column of letters until you see "B" and "A" together $(B = A \times .5774) = 6.9288$, or the length of "B."



The same applies to "C." Glance down the column of letters until you see "C" and "A" together $(C = A \times 1.1547) = (13.8564)$ or the length of "C." In all cases these are center to center measurements. "E" and "D" are used only when running parallel lines of pipe. "D" represents the spread. The same principle applies when using angle fittings as when using 90° fittings. One piece of pipe has to be longer than the other or the offsets are closer together than the rest of the run. To determine the difference in the lengths as indicated by the letter "E," you multiply the spread by the given decimal. Referring again to the formula for 60° fittings, we find "E" is obtained by multiplying "D" or the spread by .5774. We then have the length of "E," which must be added to the length of the first piece of pipe. Referring to your drawing, you will see that the piece of pipe immediately preceding the offset in your second line of pipe is longer than the corresponding piece of pipe in the first run. The offsets are the same. The piece of pipe immediately following the offset in the second run of pipe is just as much shorter than the corresponding one in the first run as it is longer preceding the offset. This same rule applies, regardless of the number of lines of pipe used.

In using the combination angles such as the 60° out of the 45°, the 45° out of the 60°, and the 60° out of the 60°, there is a rise as well as a spread. The first thing to determine is the location of the fitting on the horizontal line. To do this, square from the vertical line to the horizontal line and then, using the 60° out of the 45° as an example, multiply the spread (which is represented by "B" in View No. 1) by 1.4142. This gives the distance the 45° is set back from the square of the vertical. In other words, this gives you the length of "C," or the set back in View No. 2. The Hypotenuse is then determined by multiplying the length of "C" by 1.4142. The rise equals the spread. The procedure in figuring the other combinations is similar, excepting that the rise has to be figured. The view showing running pipe around corner on 45° angle is measured the same as a 45°, except that a 60° fitting is used.

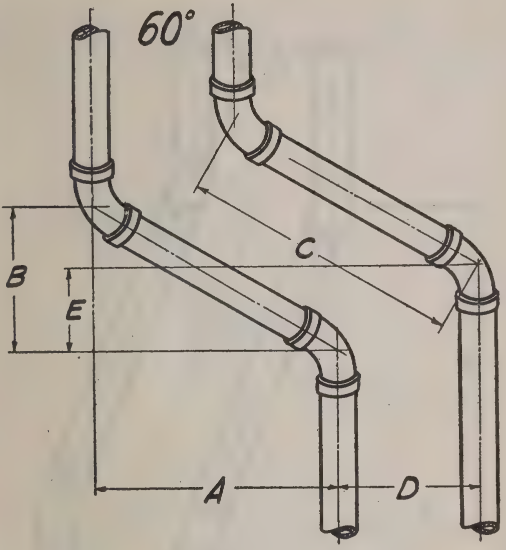


A = B

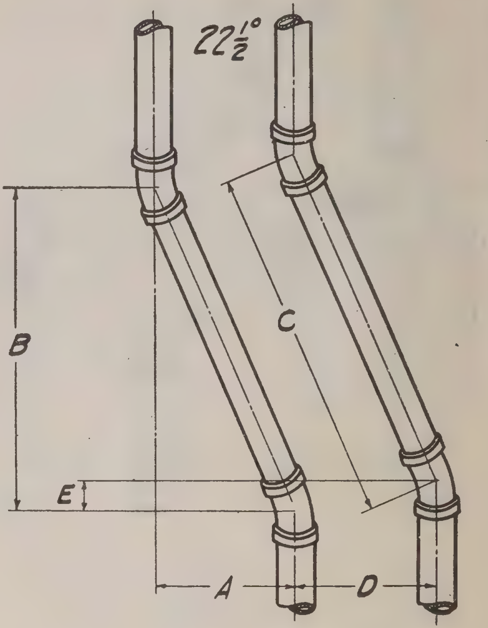
A = C × .7071

C = A × 1.4142

E = D × .4142



A = B × 1.7321
A = C × .866
B = A × .5774
B = C × .5
C = A × 1.1547
C = B × 2.00
E = D × .5774



$A = B \times .4142$

$A = C \times .3826$

$B = A \times 2.4142$

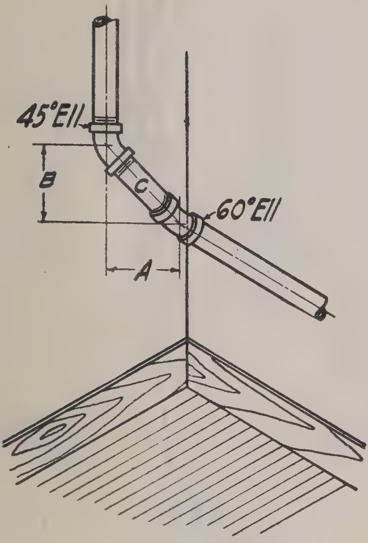
$B = C \times .921$

$B = A \times 2.6131$

$C = B \times 1.085$

$E = D \times .1985$

Running Pipe Around Corner on 45° Angle

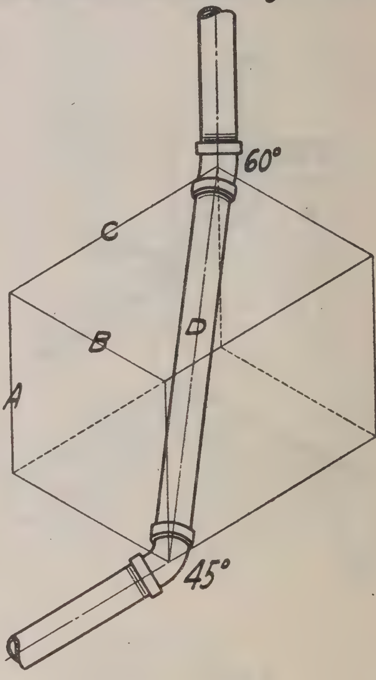

45° Ell
B
C
60° Ell
A

$A = B$

$C = A \times 1.4142$

No. 1 View

Vertical Line from Horizontal - Using 60° & 45° Ells



A = B

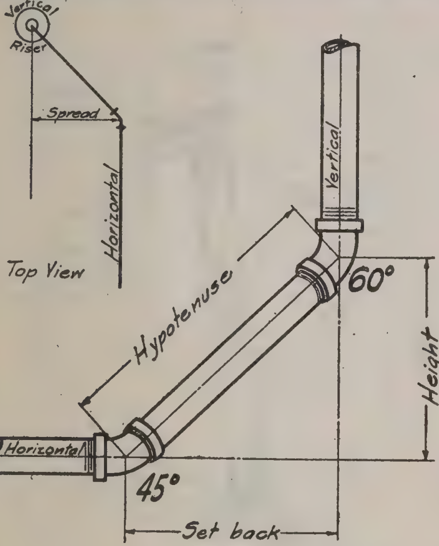
C = A × 1.4142

D = A × 2.00

D = C × 1.4142

No. 2 View

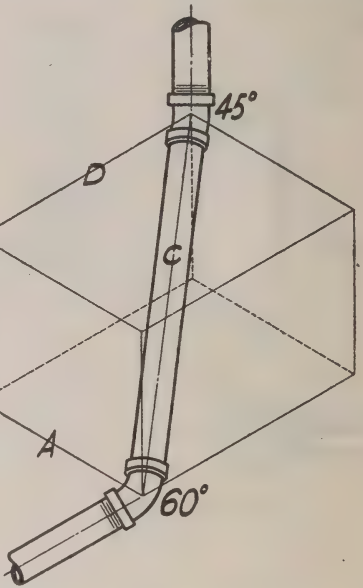
Vertical Line from Horizontal-Using 60° & 45° Ells


Vertical
Riser
Spread
Horizontal
Top View
Vertical
60°
Hypotenuse
Height
Horizontal
45°
Set back

Spread x 1.4142 = Set back
Set back x 1.4142 = Hypotenuse
Height = Spread
Hypotenuse = Spread x 2

No. 1 View·

Vertical Line from Horizontal-Using 45° & 60° Ells



A = Spread

B = A × 1.4142

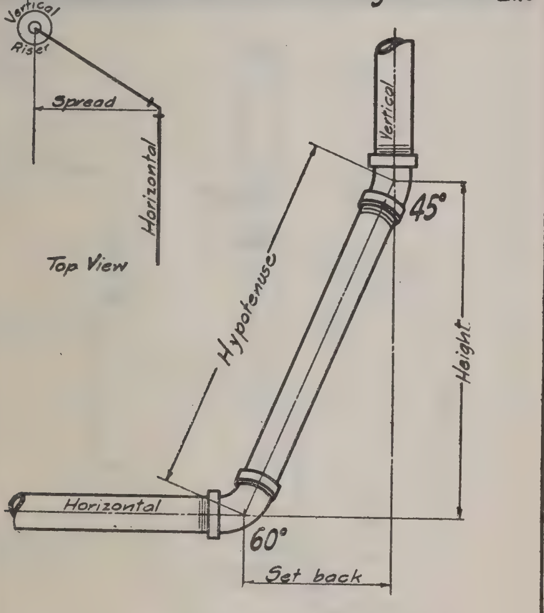
C = B × 1.4142

C = A × 2

D = A

No. 2 View

Vertical Line from Horizontal-Using 45° & 60° Ells


Vertical
Riser
Spread
Horizontal
Top View
Vertical
Hypotenuse
45°
Height
Horizontal
60°
Set back

Spread × 1.4142 = Height

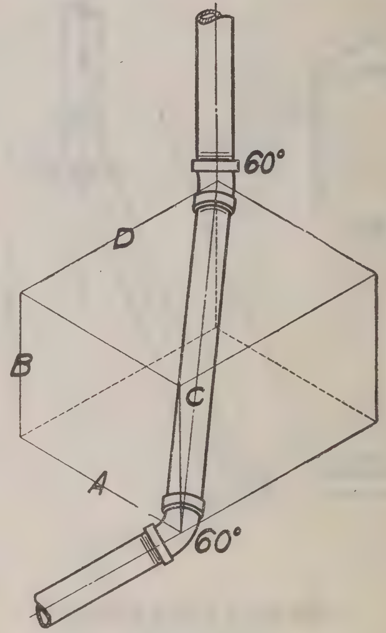
Height × 1.4142 = Hypotenuse

Spread = Set back

Hypotenuse = Spread × 2

No. 1 View

Vertical Line from Horizontal-Using two 60° Ells



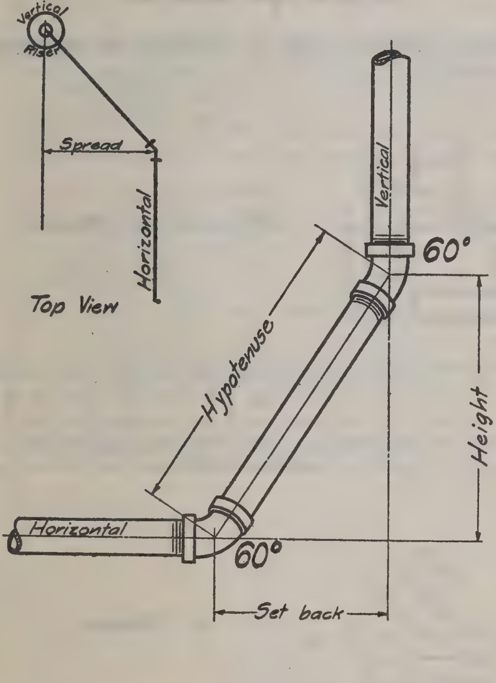
B=A × 775

C=A × 1.49

D=B

No. 2 View

Vertical Line from Horizontal - Using two 60° Ells


Vertical
Riser
Spread
Horizontal
Top View
Vertical
60°
Hypotenuse
Height
Horizontal
60°
Set back

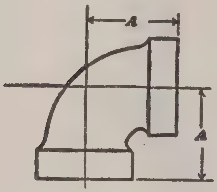
Spread × .775 = Set back

Spread × 1.49 = Hypotenuse

Height = Set back

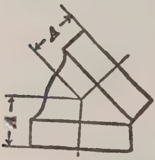
Measurements of Elbows and 45° Elbows from 1¼ in. to 8 in. Inclusive.

Extreme caution must be exercised in allowing for thread.



90° Long Turn Elbows.

Size. . Inches	1¼	1½	2	2½	3	4	5	6	7	8
Dimen. A In.	2¼	2½	$3\frac{1}{16}$	$3\frac{11}{16}$	4¼	$5\frac{3}{16}$	6⅛	7⅛	8⅛	9



45° Elbows.

Size Inches	1¼	1½	2	2½	3	4	5	6	7	8
Dimen. A In.	1⅜	$1\frac{7}{16}$	1¾	$2\frac{1}{16}$	2⅜	2¾	$3\frac{3}{16}$	3½	3⅞	$4\frac{3}{16}$

CHART
SHOWING THE MINIMUM LENGTH OF FACE TO CENTER OF DRAINAGE FITTINGS.

(CASE A) WHEN DIRECTION OF FLOW CHANGES FROM HORIZONTAL TO VERTICAL.

SIZE OF PIPE	1¼"	1½"	2"	2½"	3"	4"	5"	6"
DISTANCE FROM FACE TO CENTER (A)	1¾"	2 3/16"	2⅜"	2 13/16"	3 3/16"	3 13/16"	4½"	5 3/16"

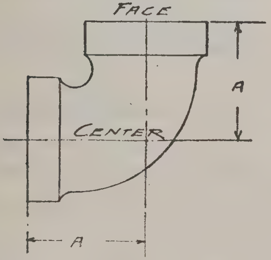
(CASE B) WHEN DIRECTION OF FLOW CHANGES FROM VERTICAL TO HORIZONTAL

SIZE OF PIPE	1¼"	1½"	2"	2½"	3"	4"	5"	6"
DISTANCE FROM FACE TO CENTER (A)	2¼"	2½"	3 1/16"	3 11/16"	4¼"	5 3/16"	6⅛"	7⅛"

(CASE C) WHEN DIRECTION OF FLOW CHANGES FROM HORIZONTAL TO HORIZONTAL

USE SAME DISTANCE FROM FACE TO CENTER AS IN CASE B.

NOTE. LONG TURN Y BRANCHES OR Y AND ⅛ BEND ARE RECOMMENDED.



Outside Diameter of Standard Wrought Iron, Steam, Gas and Water Pipe. From 1-8 to 10 Inches.

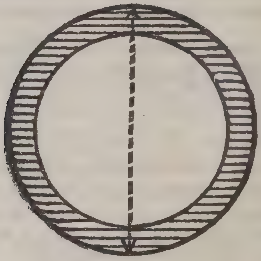


Fig. 25.

Size of pipe...........	⅛	¼	⅜	½	¾
Outside diam. of pipe..	$\frac{40}{100}$	$\frac{54}{100}$	$\frac{67}{100}$	$\frac{84}{100}$	$1\frac{5}{100}$
Size of pipe...........	1	1¼	1½	2	2½
Outside diam. of pipe..	$1\frac{31}{100}$	$1\frac{66}{100}$	$1\frac{90}{100}$	$2\frac{37}{100}$	$2\frac{87}{100}$
Size of pipe...........	3	3½	4	4½	5
Outside diam. of pipe..	$3\frac{50}{100}$	$4\frac{00}{100}$	$4\frac{50}{100}$	$5\frac{00}{100}$	$5\frac{56}{100}$
Size of pipe...........	6	7	8	9	10
Outside diam. of pipe..	$6\frac{62}{100}$	$7\frac{62}{100}$	$8\frac{62}{100}$	$9\frac{68}{100}$	$10\frac{77}{100}$

Offset Connections

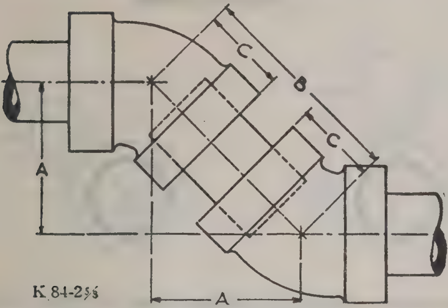
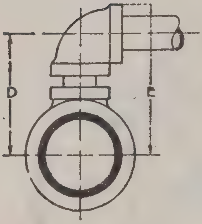


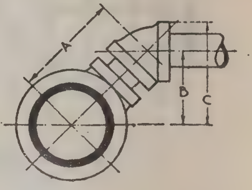
TABLE-45 DEGREE OFFSETS

Pipe Size	Close Nipple: Length of Nipple	Close Nipple: Off-set A	Close Nipple: Center to Center B	Close Nipple: Center to Face C	Short Nipple: Length of Nipple	Short Nipple: Off-set A	Short Nipple: Center to Center B	Short Nipple: Center to Face C
1/2	1 1/8	1 5/16	1 7/8	7/8	1 1/2	1 9/16	2 1/4	7/8
3/4	1 3/8	1 11/16	2 3/8	1	2	2 3/16	3	1
1	1 1/2	1 7/8	2 5/8	1 1/8	2	2 1/4	3 1/8	1 1/8
1 1/4	1 5/8	2 1/8	3	1 5/16	2 1/2	2 3/4	3 7/8	1 5/16
1 1/2	1 3/4	2 3/8	3 3/8	1 7/16	2 1/2	2 15/16	4 1/8	1 7/16
2	2	2 13/16	4	1 11/16	2 1/2	3 3/16	4 1/2	1 11/16
2 1/2	2 1/2	3 3/16	4 1/2	1 15/16	3	3 9/16	5	1 15/16
3	2 5/8	3 9/16	5	2 3/16	3	3 13/16	5 3/8	2 3/16
3 1/2	2 3/4	3 13/16	5 3/8	2 3/8	4	4 11/16	6 5/8	2 3/8
4	3	4 5/16	6 1/8	2 5/8	4	5 1/16	7 1/8	2 5/8
4 1/2	3	4 1/2	6 3/8	2 13/16	4	5 3/16	7 3/8	2 13/16
5	3 1/4	4 15/16	7	3 1/16	4 1/2	5 13/16	8 1/4	3 1/16
6	3 1/4	5 3/8	7 5/8	3 7/16	4 1/2	6 1/4	8 7/8	3 7/16
7	3 1/2	6 3/16	8 3/4	3 7/8	5	7 1/4	10 1/4	3 7/8
8	3 1/2	6 5/8	9 3/8	4 1/4	5	7 11/16	10 7/8	4 1/4

The Offset "A" Is Equal To The Distance "B" Divided By 1.414

Space Required for Branch Connections



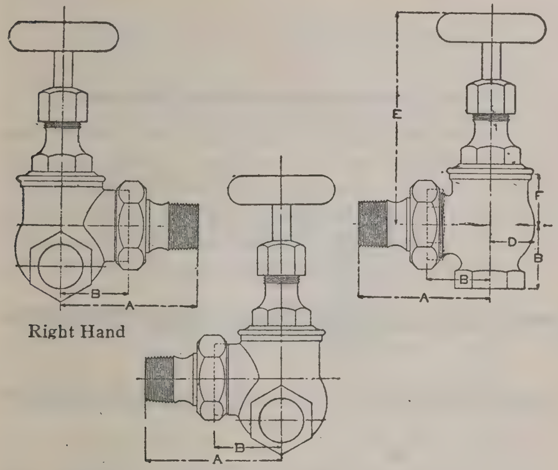


Minimum Height of Connections Off Pipe Mains

Mains Inches	Branches Inches	A In.	B In.	C In.	D In.	E In.	Branches Inches	Mains Inches
2	1	3 3/8	2 3/8	3 13/32	3 31/32	5	1	2
2	1¼	3 11/16	2 5/8	3 7/8	4 7/16	5 11/16	1¼	2
2	1½	4	2 27/32	4 7/32	4 13/16	6 3/16	1½	2
2½	1	3¾	2 21/32	3 11/16	4 11/32	5 3/8	1	2½
2½	1¼	4 1/16	2 7/8	4 1/8	4 11/16	6 1/16	1¼	2½
2½	1½	4 3/8	3 3/32	4 15/32	5 3/16	6 9/16	1½	2½
2½	2	4 7/8	3 7/16	5 1/8	5 7/8	7 9/16	2	2½
3	1	4 1/16	2 7/8	3 29/32	4 21/32	5 11/16	1	3
3	1¼	4 3/8	3 3/32	4 11/32	5 1/8	6 3/8	1¼	3
3	1½	4 11/16	3 5/16	4 11/16	5½	6 7/8	1½	3
3	2	5 5/16	3 11/16	5 3/8	6 3/16	7 7/8	2	3
3	2½	5 9/16	3 15/16	6	6 13/16	8 7/8	2½	3
3½	1	4 11/32	3 1/16	4 3/32	4 15/16	5 11/32	1	3½
3½	1¼	4 21/32	3 5/16	4 9/16	5 13/32	6 21/32	1¼	3½
3½	1½	4 31/32	3 17/32	4 29/32	5 25/32	7 5/32	1½	3½
3½	2	5 15/32	3 7/8	5 9/16	6 15/32	8 5/32	2	3½
3½	2½	5 27/32	4 1/8	6 3/16	7 3/32	9 5/32	2½	3½
4	1	4 11/16	3 5/16	4 11/32	5 9/32	6 5/16	1	4
4	1¼	5	3 17/32	4 25/32	5¾	7	1¼	4
4	1½	5 5/16	3¾	5 1/8	6 1/5	7½	1½	4
4	2	5 13/16	4 1/8	5 13/16	6 13/16	8½	2	4
4	2½	6 3/16	4 3/8	6 7/16	7 7/16	9½	2½	4
5	1¼	5 17/32	3 29/32	5 5/32	6 9/32	7 17/32	1¼	5
5	1½	5 27/32	4 1/8	5½	6 21/32	8 1/32	1½	5
5	2	6 11/32	4½	6 3/16	7 11/32	9 1/32	2	5
5	2½	6 23/32	4¾	6 13/16	7 31/32	10 1/32	2½	5
6	1¼	6 3/16	4 3/8	5 5/8	6 15/16	8 3/16	1¼	6
6	1½	6½	4 5/8	6	7 5/16	8 11/16	1½	6
6	2	7	4 31/32	6 21/32	8	9 11/16	2	6
6	2½	7 3/8	5 7/32	7 9/32	8 5/8	10 11/16	2½	6
8	2	8¼	5 27/32	7 17/32	9¼	10 15/16	2	8
8	2½	8 5/8	6 1/8	8 3/16	9 7/8	11 13/16	2½	8
8	3	9	6 3/8	8¾	10 7/16	12 13/16	3	8

The above table prepared by Fred'k D. B. Ingalls, M. E., indicates dimensions of branch connections when made up as close as possible with space nipple between tee on main and branch nipple.

Measurements of Corner and Angle Valves



Right Hand

Left Hand

Dimensions of Angle Radiator Valves

Size	½	¾	1	1¼	1½	2	2½	3
A—Centre to end of union	2 13/16	3 5/16	3¾	4	4½	4¾	5⅞	6⅞
B—Centre to face, screwed end	1⅜	1½	1 13/16	2 1/16	2¼	2 13/16	3¼	4¼
D—Radius of body	⅞	1 1/16	1¼	1½	1¾	2¼	2 11/16	3¼
E—Centre of outlet to top of hand wheel	4¾	5½	5½	6½	7	8	9	9½
F—Centre to top of body	1	1 3/16	1 5/16	1½	1 11/16	2 1/16	2 5/16	2⅞

Dimensions of Offset Corner Valves

Size	½	¾	1	1¼	1½	2
A—Centre to end of union	3	3 7/16	3¾	4⅛	4 11/16	5⅛
B—Centre to face, screwed end	1½	1⅝	2	2⅛	2 9/16	3⅛
C—Centre of outlet to centre of inlet	¾	1	1 5/32	1 3/16	1½	1 11/16
D—Radius of body	⅞	1 1/16	1¼	1½	1¾	2 3/16
E—Centre of outlet to top of hand wheel	4½	5	5⅜	6¼	7	7½
F—Centre of outlet to top of body	⅞	1 1/16	1 3/16	1 7/16	1½	2⅛

How End of Pipe Should be Reamed

If the ordinary style of fittings are used on hot water circulating systems, such as are not recessed, all ends of pipes should be carefully reamed out in a manner as shown in illustration, Fig. 22, and unless the ends of pipes are reamed, taking off at least the burr, there will not only be a large amount of friction due to such obstructions, but the capacity of the pipe will be greatly reduced by the burrs contracting the area of the pipes at each end; and while the average fitter might consider this a small matter, and in a measure a waste of time to ream the ends of pipes, he is working against his own interests if he desires to construct a good, easy, and economical working heating plant. It more than pays, in fact it is a good investment to carefully construct the pipe work of a hot water heating plant, and avoid as much as possible any cause of friction to the movement of the water.

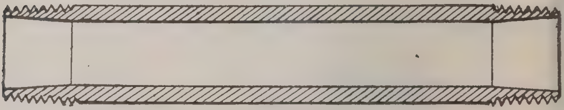
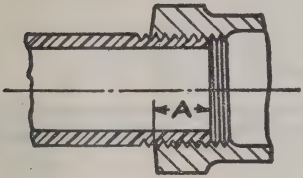


Fig. 22.

LENGTH OF THREAD ON PIPE

THAT IS SCREWED INTO VALVES OR FITTINGS TO MAKE A TIGHT JOINT



Size Inches	Dimension A Inches	Size Inches	Dimension A Inches
⅛	¼	3½	1 1/16
¼	⅜	4	1 1/16
⅜	⅜	4½	1⅛
½	½	5	1 3/16
¾	½	6	1¼
1	9/16	7	1¼
1¼	⅝	8	1 5/16
1½	⅝	9	1⅜
2	11/16	10	1½
2½	13/16	12	1⅝
3	1		

DIMENSIONS GIVEN DO NOT ALLOW FOR VARIATION IN TAPPING OR THREADING

Number of threads to the inch of screw on American standard wrought iron, steam, gas and water pipe, from ⅛ to 10 inches.

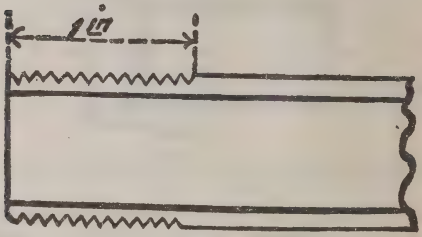
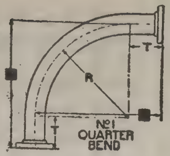
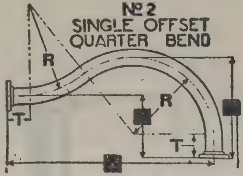


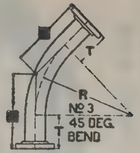
Fig. 42.

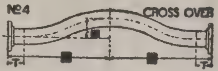
Size of pipe	⅛	¼	⅜	½	¾
Number of threads per inch	27	18	18	14	14
Size of pipe	1	1¼	1½	2	2½
Number of threads per inch	11½	11½	11½	11½	8
Size of pipe	3	3½	4	4½	5
Number of threads per inch	8	8	8	8	8
Size of pipe	6	7	8	9	10
Number of threads per inch	8	8	8	8	8

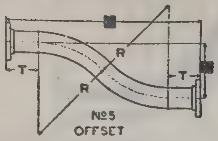
PIPE BENDS MADE FROM LAP WELDED STEEL PIPE











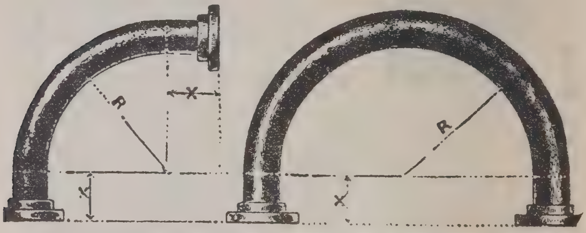
Size of Pipe . . . . . Inches	2½	3	3½	4	4½	5	6	7	8	9	10	12	14	15	16	18	20	22	24
R—Minimum Advisable Radius of Bends . . . . Inches	12½	15	17½	20	22½	25	30	35	40	45	50	60	70	75	80	108	120	132	144
Shortest Radius to which Pipe can be bent { *Standard Pipe . . Inches	10	12	14	16	18	20	26	30	34	42	45	54	70	75	80	90	104	132	144
†Extra Strong Pipe . . . . Inches	7	8	10	12	14	15	20	24	28	35	40	50	65	70	78	88	104	132	144
T—Minimum Length of Tangent or Straight Part of Bends { Screwed and Shrink . . . Inches	4	4	5	5	6	6	7	8	9	11	12	14	16	16	18	18	18	18	18
Craneweld . . . . . . Inches		5	5	5	5	5	6	6	6	6	7	7	7	7	8	8	8	9	9
Cranelap . . . . Inches		6	6	6	6	7	7	8	8	9	10	10	14	14	16	18	18	20	20

*For 14 inch O. D. PIPE and larger having $\frac{7}{16}$ inch or lighter metal. †For 14 inch O. D. PIPE and larger having ½ inch or heavier metal.

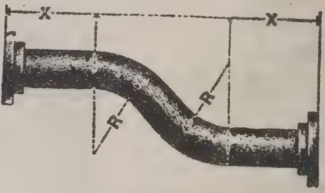
Full dimension sketch or blue print, should accompany all inquiries or orders for Bends.

Drawings submitted, should include dimensions R, T, and dimensions marked ■ where necessary, and any other variations from dimensions as given in the above table.

Illustration showing how to obtain measurements of all kinds of bends used in heavy duty work



QUARTER BENDS U BENDS



OFFSET BENDS

Fig. 7

The radius of any bend should not be less than 5 diameters of the pipe and a larger radius is much preferable. The length "X" of straight pipe at each end of bend should be not less than as follows:

2½-in. Pipe X=4 in.
3 -in. Pipe X=4 in.
3½-in. Pipe X=5 in.
4 -in. Pipe X=5 in.
4½-in. Pipe X=6 in.
5 -in. Pipe X=6 in.
6 -in. Pipe X=7 in.
7 -in. Pipe X=8 in.

8-in. Pipe X= 9 in.
10-in. Pipe X=12 in.
12-in. Pipe X=14 in.
14-in. Pipe X=16 in.
15-in. Pipe X=16 in.
16-in. Pipe X=20 in.
18-in. Pipe X=22 in.

EXPANSION BENDS

TABLE GIVING EXPANSION CARED FOR

Because of many inquiries and the necessity of having reliable data on the expansion value of pipe bends, Crane Co. made exhaustive and extensive tests on the various types of bends in several sizes and weights of pipe. The following figures giving in inches the expansion cared for by quarter bends are based on the results of these tests and are recommended as allowing a good safety factor.

Size of Pipe Inches	Minimum Radius Inches		Radius of Bends Inches										
	Standard Pipe	Extra Strong Pipe	20	30	40	50	60	70	80	90	100	110	120
2½	10	7	⅜	⅞	1½	2¼	3¼	4½	5⅞				
3	12	8	⅜	11/16	1 3/16	1⅞	2¾	3⅝	4¾	6			
3½	14	10	5/16	⅝	1	1⅝	2⅜	3¼	4¼	5⅜			
4	16	12	¼	½	15/16	1 7/16	2⅛	2⅞	3¾	4¾	5¾		
4½	18	14	¼	7/16	⅞	1 5/16	1⅞	2½	3⅜	4¼	5¼		
5	20	15		⅜	¾	1 3/16	1¾	2⅜	3	3⅞	4¾	5¾	
6	26	20		⅜	⅝	1	1½	2	2½	3¼	4	4¾	5¾
7	30	24			9/16	⅞	1 5/16	1¾	2¼	2⅞	3½	4¼	5¼
8	34	28			½	¾	1⅛	1½	2	2½	3	3¾	4⅜
10	46	40				⅝	⅞	1¼	1½	2	2½	3	3½
12	54	50				½	¾	1	1⅜	1⅝	2	2½	3
14	70	65						⅞	1⅛	1½	1¾	2⅛	2½

The above figures are for No. 1 Quarter Bends. See page 634.

For No. 7 "U" Bends multiply expansion values by 2.

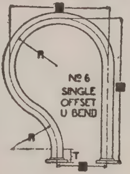
For No. 6 Single Offset Bends or No. 9 Expansion "U" Bends multiply expansion values by 4.

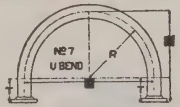
For No. 10 Double Offset Bends or No. 11 Circle Bends multiply expansion values by 5.

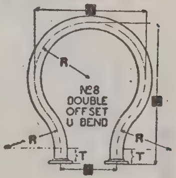
THE EXPANSION SHOWN IN THE ABOVE TABLE DOES NOT TAKE INTO CONSIDERATION SPRINGING THE BEND WHEN BOLTING INTO PLACE.

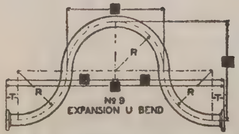
WHEN BENDS ARE SPRUNG, A DISTANCE EQUAL TO THE FIGURE GIVEN IN THE ABOVE TABLE, THEY WILL TAKE CARE OF TWICE THAT FIGURE.

EXPANSION PIPE BENDS MADE FROM LAP WELDED STEEL PIPE

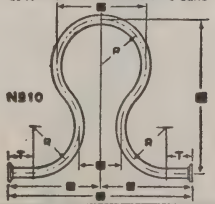

R
R
T
Nº 6
SINGLE
OFFSET
U BEND

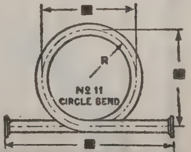

Nº 7
U BEND
R
T
T


R
R
R
T
T
Nº 8
DOUBLE
OFFSET
U BEND


R
R
R
T
T
Nº 9
EXPANSION U BEND

DOUBLE OFFSET EXPANSION U BEND




R
Nº 11
CIRCLE BEND

Size of Pipe		Inches	2½	3	3½	4	4½	5	6	7	8	9	10	12	14	15	16	18	20	22	24
R—Minimum Advisable Radius of Bends		Inches	12½	15	17½	20	22½	25	30	35	40	45	50	60	70	75	80	108	120	132	144
Shortest Radius to which Pipe can be bent	*Standard Pipe	Inches	10	12	14	16	18	20	26	30	34	42	45	54	70	75	80	90	104	132	144
	†Extra Strong Pipe	Inches	7	8	10	12	14	15	20	24	28	35	40	50	65	70	78	88	104	132	144
T—Minimum Length of Tangent or Straight Part of Bends	Screwed and Shrink	Inches	4	4	5	5	6	6	7	8	9	11	12	14	16	16	18	18	18	18	18
	Craneweld	Inches		5	5	5	5	5	6	6	6	6	7	7	7	7	8	8	8	9	9
	Cranelap	Inches		6	6	6	6	7	7	8	8	9	10	10	14	14	16	18	18	20	20

*For 14 inch O. D. PIPE and larger having $\frac{7}{16}$ inch or lighter metal. †For 14 inch O. D. PIPE and larger having ½ inch or heavier metal.

Full dimension sketch or blue print, should accompany all inquiries or orders for Bends.

Drawings submitted, should include dimensions R, T, and dimensions marked ■ where necessary, and any other variations from dimensions as given in the above table.

Expansion and Contraction.

Scarcely anything can withstand the expansion of iron. It expands from 32° to 212°, about 1-900 of its length, which in 100 feet equals 1⅜ inches. The expanding power of a 2″ pipe when heated to a temperature of 100 pounds steam, or 338°, exerts a force sufficient to move 25 tons.

Cast iron expands 1/162000 of its length for each degree Fahr. It is subjected to within ordinary limits while in its solid state.

Wrought iron expands 1/150000 of its length for each degree Fahr. To find the expansion of a line of pipe, multiply its length in inches by the number of degrees of temperature applied and divide the product by 150,000 for required expansion in inches; thus 100′ × 12″ = 1200 × 338° = 405600 ÷ 150000 = 2.7 inches.

Special attention, then, must be given to the expansion and contraction of pipes and allowance made for it.

Expansion joints should not be used if the expansion can be compensated for in any other way.

		PRESSURE STAND PIPE	
Allow for thread to screw tight in fitting	Size of opening for tapping (inches)	Bursting pressure (pounds)	Working pressure factor Safety 6 (pounds)
5/16	11/32	25,182	4,197
3/8	29/64	24,174	4,029
3/8	19/32	18,420	3,070
9/16	23/32	17,490	2,915
9/16	15/16	13,704	2,284
5/8	1 3/16	12,780	2,130
5/8	1 1/2	10,140	1,690
3/4	1 3/4	9,000	1,500
3/4	2 3/16	7,000	1,240
7/8	2 11/16	8,262	1,377
7/8	3 5/16	7,080	1,180
7/8	3 13/16	6,366	1,061
1	4 5/16	5,880	980
1	4 3/4	5,460	910
1 1/8	5 5/16	5,130	855
1 1/8	6 5/16	4,614	769
1 1/4	7 3/8	4,290	715
1 1/4	8 3/8	4,926	671
1 1/2	9 5/8	3,846	641
1 5/8	10 7/16	3,648	608
1 3/4	12 15/32	3,120	520

Table Showing Expansion of Iron Pipe for Each 100 Feet, in Inches, from 30 Degrees.

Temperature	Expansion in inches.
165 degrees	1.15
215 degrees	1.47
265 degrees	1.78
297 degrees	2.12
338 degrees	2.45

Table Showing Various Sizes of Pipe Constituting a Foot of Radiation.

Water and steam the same.

36 inches 1 -inch pipe makes 1 foot of radiation.
28 inches 1¼-inch pipe makes 1 foot of radiation.
24 inches 1½-inch pipe makes 1 foot of radiation.
20 inches 2 -inch pipe makes 1 foot of radiation.
16 inches 2½-inch pipe makes 1 foot of radiation.
13 inches 3 -inch pipe makes 1 foot of radiation.
9½ inches 3½-inch pipe makes 1 foot of radiation.
8½ inches 4 -inch pipe makes 1 foot of radiation.
6½ inches 5 -inch pipe makes 1 foot of radiation.
5½ inches 6 -inch pipe makes 1 foot of radiation.

Tables of Mains and Branches for Hot Water.

1¼ in. will supply 2 .... 1 in.
1½ in. will supply 2 .... 1¼ in.
2 in. will supply 2 .... 1½ in.
2½ in. will supply 2 1½-in. and 1 1¼-in., or 1 2 -in. and 1 1¼-in.
3 -in. will supply 1 2½-in. and 1 2 -in., or 2 2 -in. and 1 1½-in.
3½ in. will supply 2 2½-in. or 1 3 -in., and 1 2 -in. or 3 2 -in.
4 -in. will supply 1 3½-in. and 1 2½-in., or 2 3 -in. and 4 2 -in.
4½ in. will supply 1 3½-in. and 1 3 -in., or 1 4 -in. and 1 2½-in.
5 -in. will supply 1 4 -in. and 1 3 -in., or 1 4½-in. and 1 2½-in.
6 -in. will supply 2 4 -in. and 1 3 -in., or 4 3 -in. or 10 2 -in.
7 -in. will supply 1 6 -in. and 1 4 -in., or 3 4 -in. and 1 2 -in.
8 -in. will supply 2 6 -in. and 1 5 -in., or 5 4 -in. and 2 2 -in.

Size of Mains for One Pipe Hot Water System.

Do not reduce size of mains too rapidly as branches are taken off. The increased friction of smaller pipe is frequently too great to admit of any reduction in the size of main.

For direct radiation the area of the mains may be arrived at by multiplying radiating surface.

When 1800 feet and less by .011
When 2000 feet and over by .009

Use pipe having area nearest to that so found.

Under ordinary conditions, the following table for size of mains will be found entirely reliable:—

Size of Main, Inches.	Area.	Direct Radiation Will Supply, Feet.	Indirect Radiation Will Supply. Feet.
1½	2.03	200	135
2	3.35	325	200
2½	4.78	450	300
3	7.38	700	450
3½	9.82	900	600
4	12.73	1200	800
4½	15.93	1500	1000
5	19.99	2000	1200
6	28.88	3000	2000
7	38.73	4200	2800
8	50.03	5600	3600
9	63.63	7000	4600
10	78.83	8500	5600

Size of Mains for Two Pipe Hot Water System.

Size of Main. Feed: Return.	Area.	Direct Radiation will Supply, Feet.	Feet.
1½ x 1½	4.06	From 275	To 350
2 x 2	6.70	400	650
2½ x 2½	9.56	800	1000
3 x 3	14.76	1300	1500
3½ x 3½	19.64	1700	1950
4 x 4	25.46	2450	2950
4½ x 4½	31.86	3275	3500
5 x 5	39.98	3700	4450
6 x 6	57.76	5400	6050
7 x 7	77.46	7275	9400
8 x 8	100.06	11000	12400
9 x 9	127.26	14000	15500
10 x 10	157.66	17000	19000

Refer to page 42, third table, for Branches.

Size of Mains for Two Pipe Steam Systems.

In calculating on the proper size of steam mains for gravity systems, lengths of such pipes as well as the square feet of surface in same must be considered. In situations where long runs of pipe are necessary between the boiler and radiating surface proper, one size larger pipe should be used for each 100 feet, and at the same time all mains figured as radiating surface when deciding on the sizes of such main pipe.

Radiating Surface Pipe will Supply.

Size of Pipe, Feed: Return.	Area, Inches.	RADIATION.	
		Direct.	Indirect.
1¼x1	1.49	150	85
1½x1¼	2.03	225	140
2 x1¼	3.35	350	200
2½x1½	4.78	500	300
3 x2	7.38	800	500
3½x2	9.83	1100	700
4 x2½	12.73	1500	1000
4½x2½	15.93	1800	1200
5 x3	19.99	2400	1600
6 x3½	28.88	3600	2200
7 x4	38.73	5000	3000
8 x4½	50.03	6500	4000
9 x5	63.63	8000	5400
10 x6	78.83	10000	7000

Branches to radiators should always be taken off the top of the main, using a square Ell or a 45° Ell.

A practical man will always do this.

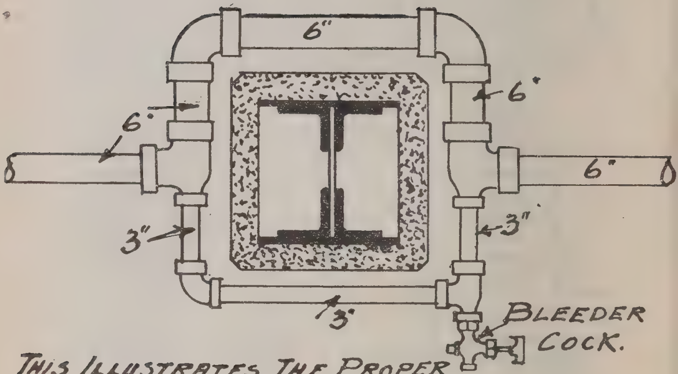
Measurement of Supply and Return Pipes.

To ascertain the amount of heating surface in supply, return pipes and risers, multiply length of pipe by figures given below, always pointing off two places.

Example: 200 lineal feet 1½-inch pipe multiplied by 50 equals 100 square feet heating surface.

Size of Pipe.	Square Feet in One Lineal Foot.	Gallons of Water in 100 Feet in Length.
¾-inch.	.27	2.77 gallons.
1 -inch.	.34	4.50 gallons.
1¼-inch.	.43	7.75 gallons.
1½-inch.	.50	10.59 gallons.
2 -inch.	.62	17.43 gallons.
2½-inch.	.75	24.80 gallons.
3 -inch.	.92	38.38 gallons.
3½-inch.	1.05	51.36 gallons.
4 -inch.	1.17	66.13 gallons.

Square Feet of Direct Steam Radiation.	Horse Power.	Size of Chimney.	Square Feet of Direct Water Radiation.
250	2.5	8x 8	400
300	3.0	8x 8	500
400	4.0	8x 8	700
500	5.0	8x12	850
600	6.0	8x12	1000
700	7.0	8x12	1200
800	8.0	12x12	1350
900	9.0	12x12	1500
1000	10.0	12x12	1700
1200	12.0	12x12	2100
1400	14.0	12x16	2400
1600	16.0	12x16	2700
1800	18.0	12x16	3000
2000	20.0	12x16	3400
2200	22 0	16x16	3700
3000	30.0	16x16	5100
3500	35.0	16x20	5900
5000	50.0	16x20	8500
5500	55.0	20x20	9300
8000	80.0	20x20	13000



This Illustrates The Proper way to Run a Main Around A Girder or Beam—To Make A Free Circulation A By-Pass with a Bleeder Cock Should Be Installed As Shown—If The Main is 6" or More The By Pass will Be Half The Size.

Sizes of Low Pressure Steam Mains One Pipe Circuit System Dripped at End

1 inch up to 60 square feet.								
1¼"	60	square	feet	to	100	square	feet.
1½"	100	"	"	"	200	"	"
2"	200	"	"	"	400	"	"
2½"	400	"	"	"	600	"	"
3"	600	"	"	"	900	"	"
3½"	900	"	"	"	1,400	"	"
4"	1,400	"	"	"	2,000	"	"
4½"	2,000	"	"	"	2,600	"	"
5"	2,600	"	"	"	3,300	"	"
6"	3,300	"	"	"	4,500	"	"
7"	4,500	"	"	"	7,000	"	"
8"	7,000	"	"	"	9,000	"	"
9"	9,000	"	"	"	11,000	"	"
10"	11,000	"	"	"	15,000	"	"
12"	15,000	"	"	"	24,000	"	"

On all piping, proper provision shall be made for expansion and contraction and shall be properly pitched.

All horizontal branches more than 12 feet in length shall be increased 2 sizes. Those more than 16 feet in length shall be properly dripped.

Supply mains shall not be reduced more than one-half the diameter of the largest main.

Dry returns shall be not less than one-half the diameter of the supply.

Wet returns may be one size smaller than one-half the diameter of the supply pipe. By supply pipe is meant the size of main at the point of leaving boiler.

Pipe Sizes for Up-Feed Risers.

1"	25 square feet or under.
1¼"	25 to 60 square feet.
1½"	60 to 100 square feet.
2"	100 to 200 square feet.
2½"	200 to 350 square feet.
3"	350 to 900 square feet.
3½"	900 to 1,200 square feet.
4"	1,200 to 2,000 square feet.

Radiator Connections

Up to and including 25 square feet	1"
Above 25 and including 60 square feet	1¼"
Above 60 and including 90 square feet	1½"
Above 90 square feet	2"

All horizontal connections to radiators shall be increased one size except branches for radiators from 91 to 130 square feet, which may be the same size as radiator connections.

All horizontal connections to risers shall be increased one size.

Rule for Computing Boiler Sizes for Direct Radiation

Schedule for computing minimum sizes of boilers for the average building based on ratings specified in the manufacturers' catalogues issued previous to March, 1916.

CAST IRON UP-DRAFT BOILERS—Size of boiler should be 80% greater than the actual amount of radiation in radiators and coils when temperature of 70° F. is required. See*.

CAST IRON DOWN-DRAFT BOILERS—Size of boiler should be 60% greater than the actual amount of radiation in radiators and coils when temperature of 70° F. is required. See*.

STEEL FIREBOX, BRICK SET, UP-DRAFT BOILERS—Size of boiler should be 35% greater than the actual amount of radiation in radiators and coils when temperature of 70° is required. See*.

STEEL FIREBOX, BRICK SET, UP-DRAFT WITH APPROVED FURNACE—To be figured on same basis as steel down draft of similar number and rating.

STEEL FIREBOX, DOWN DRAFT, BRICK SET or PORTABLE BOILERS—Size of boiler should be 45% greater than the actual amount of radiation in radiators and coils when temperature of 70° F. is required. See*.

CAST IRON MAGAZINE TYPE—Size of boiler should be 60% greater than the actual amount of radiation in radiators and coils when temperature of 70° is required. See*.

Rule for Computing Boiler Sizes for Direct-Indirect and Indirect Radiation

For computing boiler size for **direct-indirect** and **indirect** radiation, reduce same to basis of direct by adding 50% to **indirect** and 25% to **direct-indirect** and use factor of safety as called for on direct radiation.

Rules for Computing Boiler Sizes for Hot Blast Coils

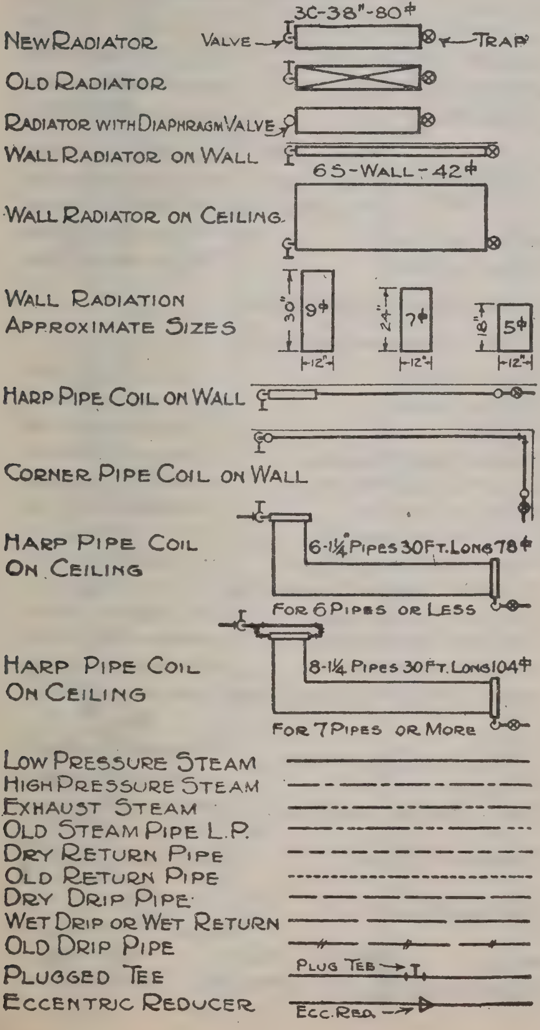
For computing boiler size to be used for Hot Blast Coils use manufacturers' condensation charts and figure ¼ lb. of condensation per hour as equivalent to 1 square foot of direct radiation and add following factor of safety:

Fire-Box, Up-draft	10%
Fire-Box, Down-draft	15%
Portable	15%
Cast-iron, Down-draft	25%
Magazine	25%
Cast-iron, Up-draft	40%

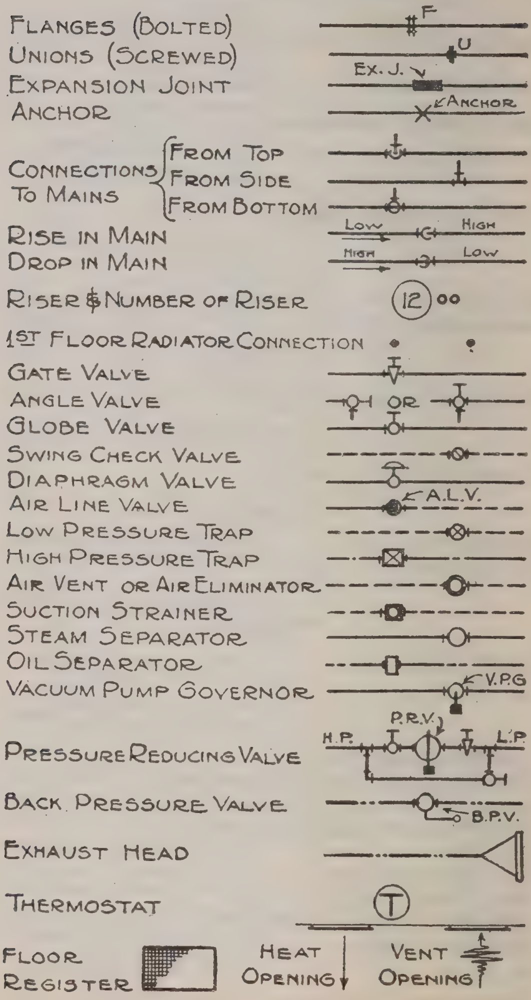
* Where coils are to be inserted in boiler for heating water for domestic purposes, size of boiler should be increased, figuring each gallon of water tank capacity as equivalent to 2 square feet of radiation. For example, a 160-gallon tank should be figured as equivalent to 320 square feet of radiation. If this is connected to an up-draft cast-iron boiler, the increased size of the boiler would be 320 plus 80% or 576 feet. If connected to a fire-box up-draft boiler, increased size of boiler should be 320 plus 35% or 432 feet.

The above schedules of quantities are commensurate with good heating results for the average building of average construction, but by no means to be construed as guarantees of the proper quantities of radiation or boiler sizes necessary to heat every building, as extraordinary conditions will of course require additional radiation or boiler capacity.

Standard Symbols


3C-38"-80#
NEW RADIATOR
VALVE
TRAP
OLD RADIATOR
RADIATOR WITH DIAPHRAGM VALVE
WALL RADIATOR ON WALL
6S-WALL-42#
WALL RADIATOR ON CEILING
WALL RADIATION APPROXIMATE SIZES
30"
9#
12"
24"
7#
12"
18"
5#
12"
HARP PIPE COIL ON WALL
CORNER PIPE COIL ON WALL
HARP PIPE COIL ON CEILING
6-1¼ PIPES 30 FT. LONG 78#
FOR 6 PIPES OR LESS
HARP PIPE COIL ON CEILING
8-1¼ PIPES 30 FT. LONG 104#
FOR 7 PIPES OR MORE
LOW PRESSURE STEAM
HIGH PRESSURE STEAM
EXHAUST STEAM
OLD STEAM PIPE L.P.
DRY RETURN PIPE
OLD RETURN PIPE
DRY DRIP PIPE
WET DRIP OR WET RETURN
OLD DRIP PIPE
PLUGGED TEE
PLUG TEE
ECCENTRIC REDUCER
ECC. RED.

Standard Symbols


FLANGES (BOLTED)
F
UNIONS (SCREWED)
U
EXPANSION JOINT
EX. J.
ANCHOR
ANCHOR
CONNECTIONS TO MAINS
FROM TOP
FROM SIDE
FROM BOTTOM
RISE IN MAIN
LOW
HIGH
DROP IN MAIN
HIGH
LOW
RISER & NUMBER OF RISER
12
1ST FLOOR RADIATOR CONNECTION
GATE VALVE
ANGLE VALVE
OR
GLOBE VALVE
SWING CHECK VALVE
DIAPHRAGM VALVE
AIR LINE VALVE
A.L.V.
LOW PRESSURE TRAP
HIGH PRESSURE TRAP
AIR VENT OR AIR ELIMINATOR
SUCTION STRAINER
STEAM SEPARATOR
OIL SEPARATOR
VACUUM PUMP GOVERNOR
V.P.G
PRESSURE REDUCING VALVE
P.R.V.
H.P.
L.P.
BACK PRESSURE VALVE
B.P.V.
EXHAUST HEAD
THERMOSTAT
T
FLOOR REGISTER
HEAT OPENING
VENT OPENING

DECIMAL EQUIVALENTS OF PARTS OF AN INCH AND CONVERSION CHART FOR METRIC LENGTHS, WEIGHTS AND TEMPERATURES

COURTESY OF THE NATIONAL TUBE COMPANY

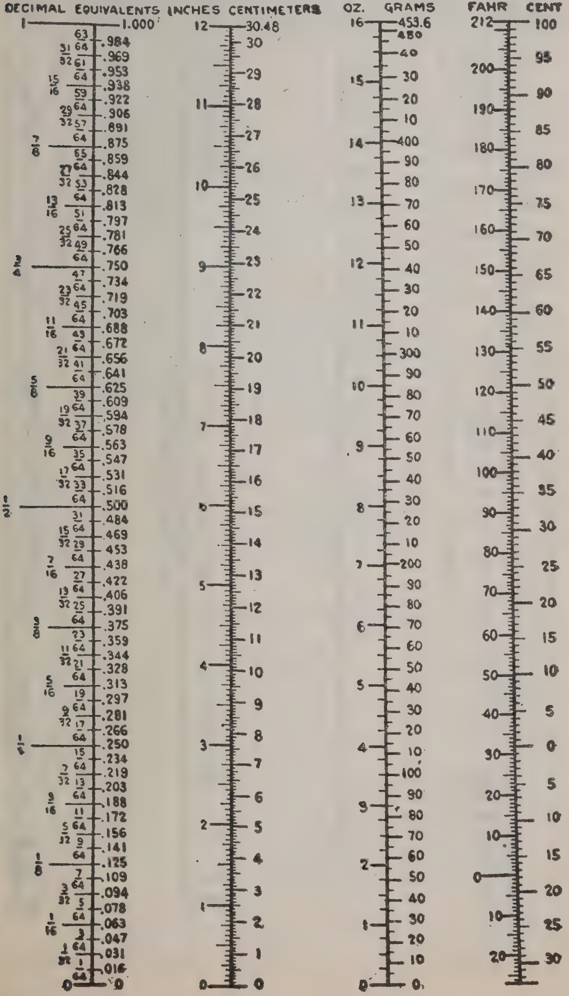


DIAGRAM FOR CALCULATING PIPE SIZES, DISCHARGE VELOCITIES, AND LOSS OF HEAD IN WATER PIPE

Lay a straight edge on scales at the points for any two known quantities and the unknown quantities will lie at the intersection of the straight edge with the other scales.

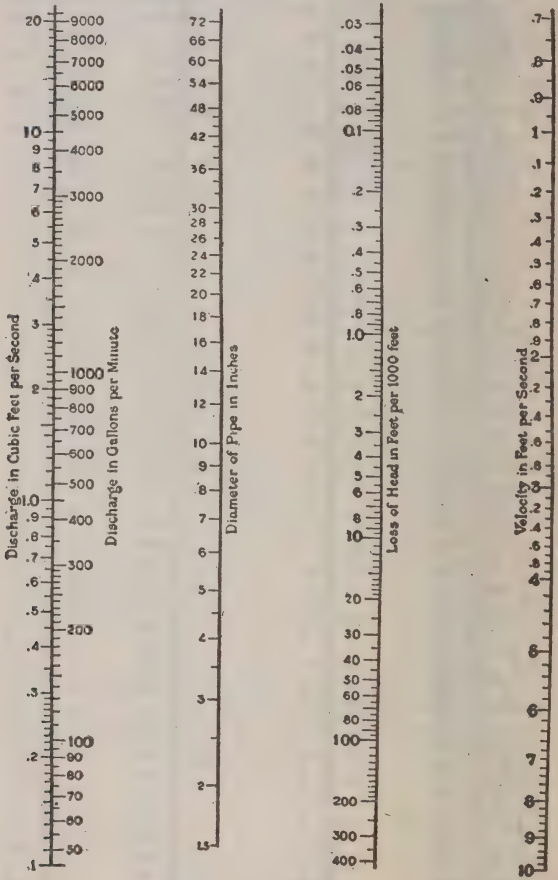


TABLE OF SIZE OF DRILL TO BE USED FOR DRILLING HOLES FOR DIFFERENT SIZES OF IRON PIPE SIZE TAPS.

DIAM. OF PIPE					
NOMINAL INSIDE	ACTUAL INSIDE	ACTUAL OUTSIDE	NUMBER OF THREADS	LENGTH OF THREAD	SIZE OF DRILL TO BE USED
1/8"	0.270	0.405	27	1/4"	5/16"
1/4"	0.364	0.540	18	3/8"	29/64
3/8"	0.494	0.675	18	3/8"	19/32"
1/2"	0.623	0.840	14	1/2"	23/32"
3/4"	0.824	1.051	14	1/2"	15/16"
1"	1.048	1.315	11 1/2	9/16"	1 3/16"
1 1/4"	1.380	1.660	11 1/2	5/8"	1 5/32"
1 1/2"	1.610	1.900	11 1/2	5/8"	1 23/32"
2"	2.067	2.375	11 1/2	11/16"	2 3/16"
2 1/2"	2.468	2.875	8	15/16"	2 11/16"
3"	3.067	3.500	8	1"	3 5/16"

SIZE OF DRILL TO BE USED FOR DIFFERENT SIZES OF MACHINE BOLT TAPS.

SIZE OF TAP	NUMBER OF THREADS	SIZE OF DRILL.
1/4"	20 PER INCH.	3/16"
5/16	18 " "	1/4"
3/8"	16 " "	19/64"
7/16"	14 " "	23/64"
1/2"	13 " "	13/32"
9/16"	12 " "	15/32"
5/8"	11 " "	33/64"
3/4"	10 " "	5/8"
7/8"	9 " "	47/64"
1"	8 " "	27/32
1 1/8"	7 " "	61/64"
1 1/4	7 " "	1 5/64"

PIPE SIZES

Thermo Modulating Heating System

Mains

Supply	Radiation	Return
2"	400	1¼"
2½"	700	1½"
3"	1250	1½"
3½"	2000	1½"
4"	3000	2"
4½"	4300	2½"
5"	5600	2½"
6"	9000	3"
7"	14000	3½"
8"	19000	4"

Risers

Supply	Radiation	Return
¾"	40	¾"
1"	80	¾"
1¼"	150	1"
1½"	220	1"
2"	500	1"
2½"	900	1¼"
3"	1500	1¼"
3½"	2100	1¼"

Horizontal Supply Branches Mains to Risers

Supply	Radiation
¾"	20
1"	60
1¼"	110
1½"	160
2"	400
2½"	700
3"	1100
3½"	1800

Horizontal Return Branches Mains to Risers

Return	Radiation
¾"	60
1"	350
1¼"	1700

Note—No supply main to be less than 2 inches; no return main less than 1¼ inches. Drip main from end of each supply main to be two sizes smaller than the smallest size of the supply main. All mains to pitch at least one inch in 15 feet in the direction of flow; all branches from mains to risers to pitch one-half inch to the foot. Tappings for radiators are to be as follows:

¾"x½" up to 100 1"x½" up to 200
1¼"x¾" up to 275

Branches from main or risers to radiators to be one size larger than valves.

Pipe Sizes. Vacuum Heating System.

TABLE 2.

Supply	Length of Main in Feet						Return
	400	600	800	1000	1500	2000	
¾"	35	30	27	25	20	17	¾"
1"	70	60	55	50	45	38	¾"
1¼"	130	110	100	90	80	66	¾"
1½"	210	180	165	150	135	112	¾"
2"	460	390	360	330	240	140	¾"
2½"	870	740	680	620	550	458	1"
3"	1430	1210	1115	1020	900	750	1¼"
3½"	2190	1850	1710	1570	1390	1160	1¼"
4"	3120	2630	2430	2230	1960	1633	1½"
4½"	4260	3510	3295	3080	2710	2260	1½"
5"	5680	4810	4500	4210	3630	3000	2"
6"	9390	7980	7350	6720	5040	4200	2½"
7"	14120	12040	11165	10290	9130	7610	3"
8"	20180	17120	15725	14330	12720	10600	3½"
9"	26920	23150	21470	19790	17380	14400	3½"
10"	35860	30890	28715	26540	23610	19700	4"
12"	57660	49950	46515	43080	38400	32000	4½"
14"	86400	75430	70370	65310	58290	48570	5"
15"				85770	71910	60000	6"

Length of main or run is based on the distance from the source of steam supply to the farthest and most remote radiator, counting in all vertical as well as horizontal travel. Source of supply to be figured from boiler unless steam pressure is reduced when run will be figured from low pressure side of pressure reducing valve. No supply main to be less than 2 inches; no return main less than 1 inch. Smaller sizes to be used only for risers and horizontal branches.

All mains to pitch not less than one inch in 40 feet in the direction of flow unless otherwise indicated on plans.

All branches from mains to risers and from risers to radiators to pitch at least one-half inch to the foot.

Tappings for all radiators when ordinary wood wheel radiator valves are to be as follows:

¾x½ up to 60 square feet.
1 x½ up to 100 square feet.
1¼x½ up to 200 square feet.
1½x¾ up to 275 square feet.
2 x¾ up to 460 square feet.

Branches from mains and risers to radiators to be one size larger than the valves.

VACUUM PUMP SIZES

TABLE 1.

Vacuum Pumps.

For use in connection with "Illinois" System of Steam Heating with Automatic Vacuum Traps.

Size	Steam	Exhaust	Suction	Discharge	Factor	Floor Space
4x5					6830	
4x4x6	⅜	½	2½	2	7270	11x34
4x4x8	⅜	½	2½	2	8000	11x34
5x5					10680	
4x5x6	¾	½	3	2½	11353	13x36
4x5x8	⅜	½	3	2½	12500	13x38
4½x5½x8	½	¾	3		15125	13x38
6x5					15990	
6x7					17215	
4½x6x8	½	¾	3	2½	18000	13x38
5x6x10	¾	1	4	3	19390	18x50
7x7¼x10	1	1¼	5	4	28256	18x52
6x7½x12	¾	1	3	4	30605	19x54
7x8x16	1	1¼	5	4	34470	18x52
6x8x12	¾	1	5	4	36620	19x54
9x10					43627	
8x9¼x12	1	1½	6	5	48951	20x58
8x10x12	1	1½	6	5	57220	20x58
10x14					60250	
10x12x12	1¼	1½	6	5	82997	20x62
10x16					90713	
14x16					122500	
12x14x20	1½	2	10	8	133000	
16x16					161270	
14x16x20	2	2½	12	10	173720	
16x18x20	2½	3	12	10	219870	
18x24					233640	
18x20x20	3	3½	14	12	271440	

Note—Steam ends to be proportioned to steam pressure available.

These Tables Apply to Vacuum Heating.

Vacuum pump formula on basis of 80" pressure.

Radiation + (No. of units x 100) = Factor.

Example— What size pump is required for 5000 sq. ft. of surface in 150 radiators?

5000 + (150x100) = 20000.

Use a 5x6x10 pump.

For lower steam pressure, proportion the steam end accordingly.

Water Capacity of a Boiler.

To find the water capacity of any horizontal tubular boiler, 1-3 being allowed for water space.

1. Multiply area of head by length of boiler in inches.
2. Multiply area of one tube by length and the result by number of tubes.
3. Deduct amount given from first amount and divide by 231 (cubic inches in gal.) quotient will be answer in gallons. Take ⅔ for amount wanted.

Example.

Boiler, 6 feet by 18 inches. 100 3-inch tubes.

Length of tubes	216
Area of tubes	7
	1512
Number of tubes	100
	151200 cu.in.
Area of boiler......................	4071.51
Length of boiler....................	216
	24429.06
	40715.1
	814302
Total cubic inches boiler	879446.16
Deduct cubic inches in tubes	151200
Divide by 231 (cubic inches in gallon)	231)728246.16(3152.58
	693
	352
	231
	1214
	1155
	596
	462
	1341
	1155
Answer ⅔ of 3152.58=2101.71.	1866

Horizontal Fire Box Boilers for Steam and Hot Water Heating

Diam. of Shell........inches	30	30	30	36	36	36	42	42	42	48	48	48	54	54
Length over all..........feet	6½	7½	8½	7½	9	10½	8½	10	11½	10½	12	13½	14	16½
Number of Tubes............	40	40	40	40	40	40	52	52	52	48	48	48	34	34
Diam. of Tubes.......inches	2	2	2	2½	2½	2½	2½	2½	2½	3	3	3	4	4
Fire Doors.														
Single Doors........inches	12x18	12x18	12x18	......	......	......	......	......	......	......	......	......	......	......
Double Doors.......inches	......	......	......	16x22	16x22	16x22	16x24	16x24	16x24	18x30	18x30	18x30	18x30	18x30
Steam Tappings.														
Steam Outlet. ......inches	3	3	4	4	4	4	4	6	6	6	6	6	7	7
Return Inlet........inches	2½	2½	3	3	3	3	3	4	4	4	4	4	5	5
Water Tappings.														
Flow and Return....inches	3	3	3½	3½	4	4	4	5	5	5	6	6	7	7
Tapping for Safety Valve ....inches	1	1	1	1¼	1¼	1¼	1½	1½	1½	2	2	2	2½	2½
Size of Smoke Pipe....inches	14	14	14	16	16	16	18	18	18	22	22	22	24	24
Total Heating Surface..sq. ft.	152	172	194	211	252	292	295	347	399	421	482	541	580	720
Grate Area.............sq. ft.	4.3	5.3	6.3	6.7	8	9.2	9.5	11	12.5	13	14.7	16.4	18.6	20.6
Radiation will carry, Direct Steam................	850	950	1100	1200	1500	1800	1800	2200	2600	2800	3300	3800	4500	5800
Radiation will carry, Direct Water,............	1350	1500	1750	1900	2400	2900	2900	3500	4200	4500	5300	6100	7200	9300

Horizontal Tubular Boilers.

Diam of Shell.	Length of Shell.	No. of Tubes.	Diam. of Tubes.	Length of Tubes.	Gauge of Shell.	Gauge of Heads	Heat'g Surface	Horse Power
60	19	65	3½	18	⅜	½	1147	**76**
60	18	65	3½	17	⅜	½	1074	**72**
60	17	65	3½	16	⅜	½	1006	**67**
60	17	92	3	16	⅜	7/16	1229	**82**
60	16	92	3	15	⅜	7/16	1152	77
60	15	92	3	14	⅜	7/16	1075	72
60	14	92	3	13	⅜	7/16	998	67
54	19	50	3½	18	5/16	½	951	63
54	18	50	3½	17	5/16	½	900	60
54	17	50	3½	16	5/16	½	795	53
54	17	72	3	16	5/16	7/16	977	65
54	16	72	3	15	5/16	7/16	917	61
54	15	72	3	14	5/16	7/16	857	57
54	14	72	3	13	5/16	7/16	797	53
54	13	72	3	12	5/16	7/16	735	49
48	17	40	3½	16	5/16	⅜	683	46
48	17	49	3	16	5/16	⅜	684	46
48	16	49	3	15	5/16	⅜	642	43
48	15	49	3	14	5/16	⅜	600	40
48	14	49	3	13	5/16	⅜	555	37
48	13	49	3	12	5/16	⅜	513	34
48	12	65	2½	11	5/16	⅜	542	36
42	16	38	3	15	¼	⅜	508	34
42	15	38	3	14	¼	⅜	476	32
42	14	38	3	13	¼	⅜	441	30
42	13	38	3	12	¼	⅜	408	27
42	12	45	2½	11	¼	⅜	390	26
42	11	45	2½	10	¼	⅜	355	24
42	10	45	2½	9	¼	⅜	320	22
42	9	45	2½	8	¼	⅜	285	19
42	8	45	2½	7	¼	⅜	248	16
36	13	28	3	12	¼	⅜	306	20
36	12	34	2½	11	¼	⅜	298	20
36	11	34	2½	10	¼	⅜	271	18
36	10	34	2½	9	¼	⅜	244	16
36	9	34	2½	8	¼	⅜	211	14
36	8	34	2½	7	¼	⅜	190	12
30	9	30	2	8	¼	⅜	152	10
30	8	30	2	7	¼	⅜	133	8
30	7	30	2	6	¼	⅜	114	7
30	6	30	2	5	¼	⅜	95	6

MEASUREMENTS FOR SETTING HORIZONTAL TUBULAR BOILERS
FULL FLUSH FRONT

HORSE POWER		15	20	25	30	35	40	45	50	60	70	80	90	100	110	125	150	165	180	200
DIAM. OF BOILERS	A	36"			44			48"		54"		60"		66"		72"			78"	
LENGTH OF BOILERS	B	8'	10'	12'	10'	12'	14'	12'	14	14	16'	16	18'	16'	18'	16'	18'	20'	18'	20'
DEPTH OF SMOKE EXTENSION	C	12"	12"	12"	14"	14"	14"	16"	16"	16"	16"	18"	18"	18"	18"	20"	20"	20"	20"	20"
WIDTH OF HEARTH PLATE	D	9"	9"	9"	14"	14"	14"	14"	14"	14"	14"	14"	14"	14"	14"	17"	17"	17"	17"	17"
LENGTH OF GRATES	E	36"	36"	42"	36"	42"	48"	42"	48"	48"	54"	54"	60"	54"	60"	54"	60"	66"	60"	66"
WIDTH OF GRATES	F	36"	36"	36"	42"	42"	42"	48"	48"	54"	54"	60"	60"	66"	66"	72"	72"	72"	78"	78"
THICKNESS OF BRIDGE WALL	G	18"	18"	18"	20"	20"	20"	24"	24"	24"	24"	28"	28"	30"	30"	30"	30"	30"	30"	30"
HEIGHT OF DEAD PLATE ABOVE FLOOR	H	18"	18"	18"	21"	21"	21"	22"	22"	22"	22"	24"	24"	25"	25"	26½"	26½"	26½"	27"	27"
DEAD PLATE TO BOTTOM OF BOILER	I	17"	17"	17"	21"	21"	21"	23"	23"	23"	23"	25"	25"	25"	25"	29"	29"	29"	29"	29"
HEIGHT OF FRONT	J	6'-5"	6'-5"	6'-5"	7'-6"	7'-6"	7'-6"	8'-1"	8'-1"	8'-7"	8'-7"	9'-5"	9'-5"	10'-0"	10'-0"	11'-0"	11'-0"	11'-0"	11'-8"	11'-8"
TOP OF BRIDGEWALL TO BOILER	K	8"	8"	8"	10"	10"	10"	10"	10"	12"	12"	12"	12"	14"	14"	14"	14"	14"	14"	14"
DEPTH OF COMBUSTION CHAMBER	L	20"	20"	20"	24"	24"	24"	24"	24"	24"	24"	28"	28"	28"	28"	30"	30"	30"	30"	30"
THICKNESS OF REAR WALL	M	16"	16"	16"	16"	16"	16"	16"	16"	20"	20"	20"	20"	20"	20"	20"	20"	20"	20"	20"
HEIGHT TO REAR END OF BOILER	N	34"	34"	34"	41"	41"	41"	44"	44"	44"	44"	48"	48"	49"	49"	54½"	54½"	54½"	55"	55"
THICKNESS OF BOILER SIDE WALLS	O	13"	13"	13"	13"	13"	13"	17"	17"	17"	17"	21"	21"	21"	21"	21"	21"	21"	25"	25"
THICKNESS OF FURNACE SIDE WALLS	P	16"	16"	16"	16"	16"	16"	20"	20"	20"	20"	24"	24"	24"	24"	24"	24"	24"	28"	28"
DISTANCE BETWEEN BOILER SIDE WALLS	Q	42"	42"	42"	50"	50"	50"	54"	54"	60"	60"	66"	66"	72"	72"	78"	78"	78"	84"	84"
WIDTH OF SETTING	R	5'-8"	5'-8"	5'-8"	6'-4"	6'-4"	6'-4"	7'-4"	7'-4"	7'-10"	7'-10"	9'-0"	9'-0"	9'-6"	9'-6"	10'-0"	10'-0"	10'-0"	11'-2"	11'-2"
LENGTH OF SETTING	S	12'-0"	14'-0"	16'-0"	14'-6"	16'-6"	18'-6"	16'-8"	18'-8"	19'-0"	21'-0"	21'-6"	23'-6"	21'-6"	23'-6"	21'-10"	23'-10"	25'-10"	23'-10"	25'-10"
FRONT OF SETTING TO BRIDGEWALL	T	3'-7"	3'-7"	4'-1"	4'-6"	4'-6"	5'-0"	4'-6"	5'-0"	5'-0"	5'-6"	5'-6"	6'-0"	5'-6"	6'-0"	5'-9"	6'-1"	6'-9"	6'-1"	6'-9"

MEASUREMENTS FOR SETTING HORIZONTAL TUBULAR BOILERS

HALF ARCH FRONT

HORSE POWER		15	20	25	30	35	40	45	50	60	70	80	90	100	110	125	150	165	180	200
DIAM. OF BOILERS	A	36"			44"			48"		54"		60"		66"		72"			78"	
LENGTH OF BOILERS	B	8'	10'	12'	10'	12'	14'	12'	14'	14'	16'	16'	18'	16'	18'	16'	18'	20'	18'	20'
DEPTH OF SMOKE EXTENSION	C	12"	12"	12"	14"	14"	14"	16"	16"	16"	16"	18"	18"	18"	18"	20"	20"	20"	20"	20"
WIDTH OF HEARTH PLATE	D	5"	5"	5"	5"	5"	5"	9"	9"	9"	9"	9"	9"	9"	9"	9"	9"	9"	13"	13"
LENGTH OF GRATES	E	36"	36"	42"	36"	42"	48"	42"	48"	48"	54"	54"	60"	54"	60"	54"	60"	66"	60"	66"
WIDTH OF GRATES	F	36"	36"	36"	42"	42"	42"	48"	48"	54"	54"	60"	60"	66"	66"	72"	72"	72"	78"	78"
THICKNESS OF BRIDGEWALL	G	18"	18"	18"	20"	20"	20"	24"	24"	24"	24"	28"	28"	30"	30"	30"	30"	30"	30"	30"
HEIGHT OF DEAD PLATE ABOVE FLOOR	H	18"	18"	18"	21"	21"	21"	22"	22"	22"	22"	24"	24"	25"	25"	26½"	26½"	26½"	27"	27"
DEAD PLATE TO BOTTOM OF BOILER	I	17"	17"	17"	21"	21"	21"	23"	23"	23"	23"	25"	25"	25"	25"	29"	29"	29"	29"	29"
HEIGHT TO CENTER OF BOILER	J	4'-5"	4'-5"	4'-5"	5'-4"	5'-4"	5'-4"	5'-9"	5'-9"	6'-0"	6'-0"	6'-7"	6'-7"	6'-11"	6'-11"	7'-7½"	7'-7½"	7'-7½"	7'-11"	7'-11"
TOP OF BRIDGEWALL TO BOILER	K	8"	8"	8"	10"	10"	10"	10"	10"	12"	12"	12"	12"	14"	14"	14"	14"	14"	14"	14"
DEPTH OF COMBUSTION CHAMBER	L	20"	20"	20"	24"	24"	24"	24"	24"	24"	24"	28"	28"	28"	28"	30"	30"	30"	30"	30"
THICKNESS OF REAR WALL	M	16"	16"	16"	16"	16"	16"	16"	16"	20"	20"	20"	20"	20"	20"	20"	20"	20"	20"	20"
HEIGHT TO REAR END OF BOILER	N	34"	34"	34"	41"	41"	41"	44"	44"	44"	44"	48"	48"	49"	49"	54½"	54½"	54½"	55"	55"
THICKNESS OF BOILER SIDE WALLS	O	13"	13"	13"	13"	13"	13"	17"	17"	17"	17"	21"	21"	21"	21"	21"	21"	21"	25"	25"
THICKNESS OF FURNACE SIDE WALLS	P	16"	16"	16"	16"	16"	16"	20"	20"	20"	20"	24"	24"	24"	24"	24"	24"	24"	28"	28"
DISTANCE BETWEEN BOILER SIDE, WALLS	Q	42"	42"	42"	50"	50"	50"	54"	54"	60"	60"	66"	66"	72"	72"	78"	78"	78"	84"	84"
WIDTH OF SETTING	R	5'-8"	5 8"	5'-8"	6'-4"	6'-4"	6'-4"	7'-4"	7'-4"	7'-10"	7'-10"	9'-0"	9'-0"	9'-6"	9'-6"	10'-0"	10'-0"	10'-0"	11'-2"	11'-2"
LENGTH OF SETTING	S	10'-10"	12'-10"	14'-10"	13'-2"	15'-2"	17'-2"	15'-2"	17'-2"	17'-6"	19'-6"	19'-10"	21'-10"	19'-10"	21'-10"	20'-0"	22'-0"	24'-0"	22'-0"	24'-0"
FRONT OF SETTING TO BRIDGEWALL	T	3'-3"	3'-3"	3'-9"	3'-3"	3'-9"	4'-3"	4'-1"	4'-7"	4'-7"	5 1"	5'-1"	5'-7"	5'-1"	5'-7"	5'-1"	5'-7"	6'-1"	5'-11"	6'-5"

Materials for Brickwork of Firebox Boilers
12-inch Walls

Boilers In. Ft.	Brick	Sand, Bushels	Cement, Barrels	Lime, Barrels
30 x 6½......	2400	20	2½	1
30 x 7½......	2650	21	2½	1
30 x 8½......	2900	23	2¾	1¼
36 x 7½......	3150	25	3	1½
36 x 9	3550	28	3½	1¾
36 x 10½......	4000	31	4	2
42 x 8½......	4000	31	4	2
42 x 10	4600	38	5	2¼
42 x 11½......	5100	41	5½	2¼
48 x 10½......	4900	40	5½	2½
48 x 12	5400	43	5¾	2½
48 x 13½......	5800	46	6	2¾
54 x 14	6900	54	6¾	3
54 x 16½......	7500	59	7¾	3½

Materials for Brickwork of Firebox Boilers
9-inch Walls

Boilers In. Ft.	Brick	Sand, Bushels	Cement, Barrels	Lime, Barrels
30 x 6½......	1640	14	1½	1
30 x 7½......	1820	15	1¾	1
30 x 8½......	1980	16	2	1¼
36 x 7½......	2240	18	2¼	1½
36 x 9	2520	20	2¾	1¾
36 x 10½......	2870	23	3	2
42 x 8½......	2870	23	3	2
42 x 10	3400	27	3½	2¼
42 x 11½......	3800	30	4	2½
48 x 10½......	3600	29	3¾	2¼
48 x 12	3860	30	4	2½
48 x 13½......	4140	33	4½	2¾
54 x 14	5150	41	5½	3
54 x 16½......	5550	43	5¾	3¼

Materials for Brickwork of Regular Tubular Boilers.

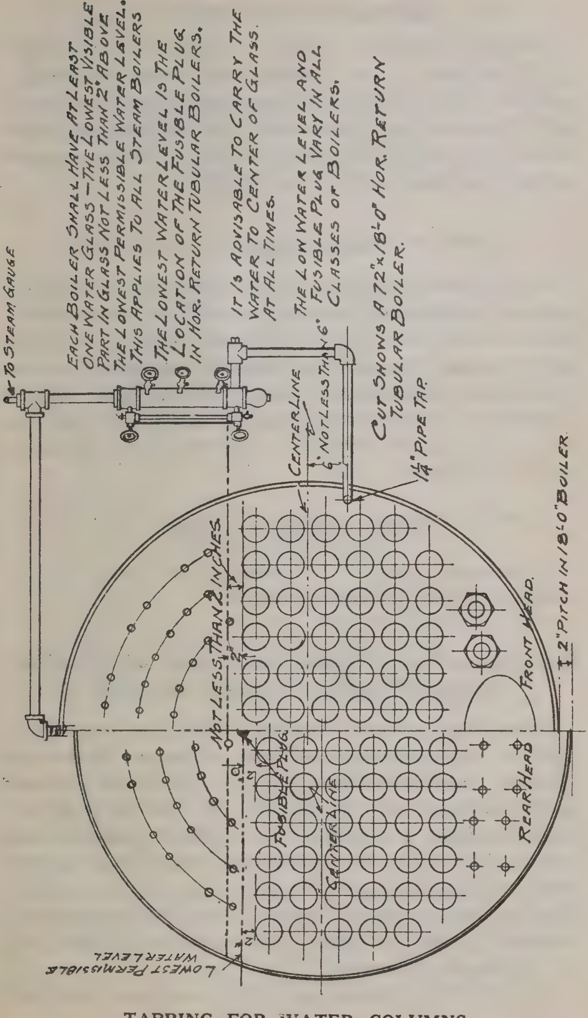
Two Boilers in a Battery.

Boilers. In. Ft.	Common Brick.	Fire Brick.	Sand, Bushels.	Cement, Barrels.	FireClay, Lbs.	Lime, Barrels
30 x 8	8900	640	70	9	384	3½
30 x 10	9600	640	76	9½	384	4
36 x 8	10500	960	84	10½	576	4¼
36 x 9	11100	960	88	11	576	4½
36 x 10	11800	960	95	12	576	4¾
36 x 12	13000	960	104	13	576	5¼
42 x 10	17500	1440	140	17½	864	7
42 x 12	18600	1440	148	18½	864	7½
42 x 14	19900	1440	159	20	864	8
42 x 16	21200	1440	168	21	864	8½
48 x 10	21400	1960	170	21½	1180	8¾
48 x 12	22300	1960	178	22⅓	1180	9
48 x 14	23900	1960	190	24	1180	9½
48 x 16	25100	1960	200	25	1180	10
54 x 12	23300	2300	186	23⅓	1380	9⅓
54 x 14	24800	2300	198	25	1380	10
54 x 16	26300	2300	210	26⅓	1380	10½
60 x 10	22600	2560	180	22½	1536	9
60 x 12	24800	2560	198	25	1536	10
60 x 14	26800	2560	214	27	1536	10¾
60 x 16	28900	2560	230	29	1536	11½
60 x 18	31000	2560	248	31	1536	12½
66 x 16	33100	2800	264	33	1680	13¼
72 x 16	34000	3100	272	34	1860	13¾

Materials for Brickwork of Regular Tubular Boilers

Single Setting.

Boilers. In. Ft.	Common Brick.	Fire Brick.	Sand, Bushels.	Cement, Barrels.	Fire Clay, Lbs.	Lime' Bbls.
30 x 8	5200	320	42	5	192	2
30 x 10	5800	320	46	5½	192	2¼
36 x 8	6200	480	50	6	288	2½
36 x 9	6600	480	53	6½	288	2¾
36 x 10	7000	480	56	7	288	3
36 x 12	7800	480	62	8	288	3¼
42 x 10	10000	720	80	10	432	4
42 x 12	10800	720	86	11	432	4¼
42 x 14	11600	720	92	11¾	432	4½
42 x 16	12400	720	99	12½	432	5
48 x 10	12500	980	100	12½	590	5¼
48 x 12	13200	980	108	13½	590	5½
48 x 14	14200	980	116	14½	590	5¾
48 x 16	15200	980	124	15½	590	6
54 x 12	13800	1150	108	13¾	690	5½
54 x 14	14900	1150	117	15	690	6
54 x 16	16000	1150	126	16	690	6¼
60 x 10	13500	1280	108	13½	768	5½
60 x 12	14800	1280	118	14¾	768	6
60 x 14	16100	1280	128	16	768	6½
60 x 16	17400	1280	140	17½	768	7
60 x 18	18700	1280	148	18¾	768	7½
66 x 16	19700	1400	157	19¾	840	8
72 x 16	20800	1550	166	20¾	930	8½


TO STEAM GAUGE
EACH BOILER SHALL HAVE AT LEAST ONE WATER GLASS — THE LOWEST VISIBLE PART IN GLASS NOT LESS THAN 2" ABOVE THE LOWEST PERMISSIBLE WATER LEVEL. THIS APPLIES TO ALL STEAM BOILERS
THE LOWEST WATER LEVEL IS THE LOCATION OF THE FUSIBLE PLUG IN HOR. RETURN TUBULAR BOILERS.
IT IS ADVISABLE TO CARRY THE WATER TO CENTER OF GLASS AT ALL TIMES.
THE LOW WATER LEVEL AND FUSIBLE PLUG VARY IN ALL CLASSES OF BOILERS.
CUT SHOWS A 72"x18'-0" HOR. RETURN TUBULAR BOILER.
B
CENTER LINE
NOT LESS THAN 6"
6"
1¼" PIPE TAP
NOT LESS THAN 2 INCHES
2"
FRONT HEAD
2" PITCH IN 18'-0" BOILER
FUSIBLE PLUG
CENTER LINE
REAR HEAD
2"
LOWEST PERMISSIBLE WATER LEVEL

TAPPING FOR WATER COLUMNS

Heating Surface of Boilers.

In considering the question, "What is good and proper heating surface in steam boilers?" we take the horizontal tubular style of boilers as the standard, and any construction of cast or wrought iron boiler with as good heating surface may be figured in the same manner as to capacity.

Boiler Capacity.

If you wish to install a boiler that will be economical and require only moderate attention, do not select a boiler with a rating agreeing with the surface to be heated. Allow from 15 to 25 per cent. reserve power for emergencies—remembering that other factors beside the radiation affect the boiler, such as the care or management it receives, the fuel used and the chimney draft.

Rating of Tubular Boilers.

In figuring radiation, for every horse power allow 100 square feet of direct radiation.

Determining Size of Boiler when Pipe Coil is used for Heating Water for Domestic Purposes.

When a pipe coil or cast iron section is introduced into the firepot for the purpose of heating water for domestic use, additional capacity should be figured in determining size of Boiler, viz., in the case of Steam Boilers, 1¼ square feet of direct radiation for each gallon of water to be thus heated, and in the case of Water Boilers, 2 square feet of direct radiation for each gallon of water to be thus heated, according to the capacity of the tank to which coil or section is connected.

When indirect radiation is to be used, not less than

75 per cent increase over direct radiation should be figured in determining the size of boiler required.

In rating steam boilers as above, it is understood that an average pressure of two pounds will be maintained at the Boiler. In rating water boilers as above, it is understood that the mean temperature of the water at the Boiler will be 180 degrees Fahrenheit.

Size of Fresh Air Inlets to Indirect Stacks.

Where natural draught is depended upon for the movement of cold air to the indirect stacks of steam radiation, practice has found that for each square foot of radiation 1½ square inches of opening for cold air supply is necessary, or, in other words, for each 10 square feet of indirect radiation 15 square inches of cold air opening will answer.

The Amount of Direct Radiation that can be Heated by Exhaust Steam.

In calculating the heating capacity of an engine from its exhaust steam, there will be some difference in the make or style of such engine from which the exhaust steam is taken, and the better the engine the less will be the heating capacity per horse power of such engine from its exhaust steam; at the same time it will be a safe plan, based on practical experience, to allow from 100 to 125 feet of direct radiation per horse power of engine from which the exhaust steam is taken. Condensing engines, of course, not being considered for such purposes.

In exhaust steam heating plants where the feed water is heated by the exhaust steam, much of the heat from the exhaust steam will be extracted from the exhaust system by the feed water; and therefore this must be taken into consideration.

Illustration Showing Best Methods of Making One Pipe Steam Radiator Connection.

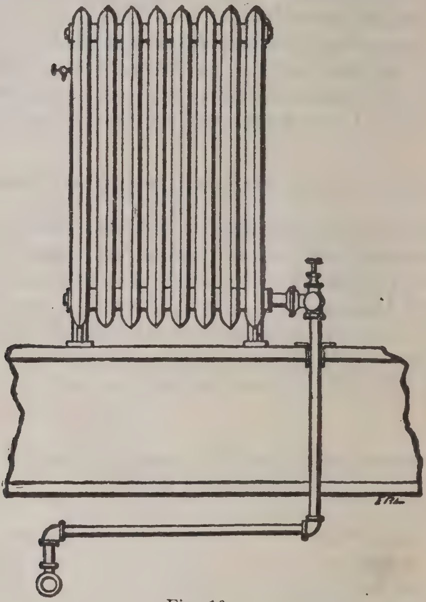
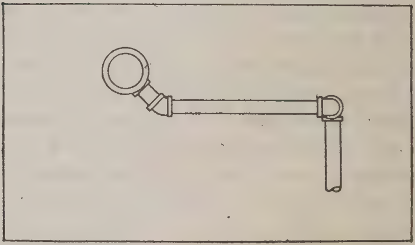


Fig. 10.



Typical Method of Connecting Risers to Over Head Mains, Allowing for Contraction and Expansion

Method of Connecting Radiator to Riser on One Pipe Steam System.

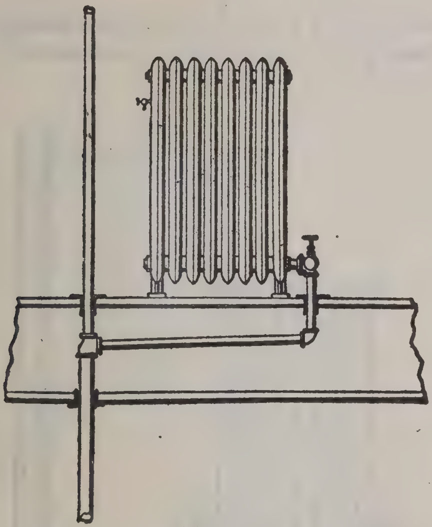
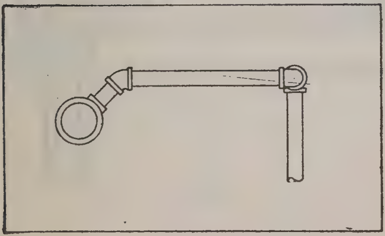


Fig. 11.



Typical Method of Connecting Risers to Over Head Mains, Allowing for Contraction and Expansion

Figures 12, 13, 14 and 15 Show Best Methods of Making Hot Water Radiator Connections.

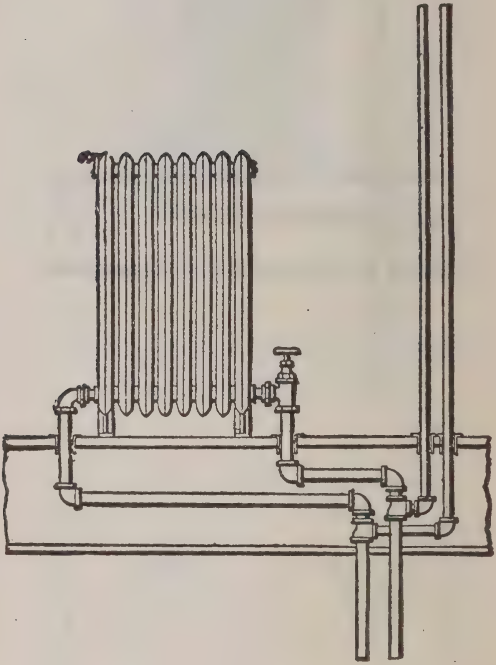


Fig. 12.

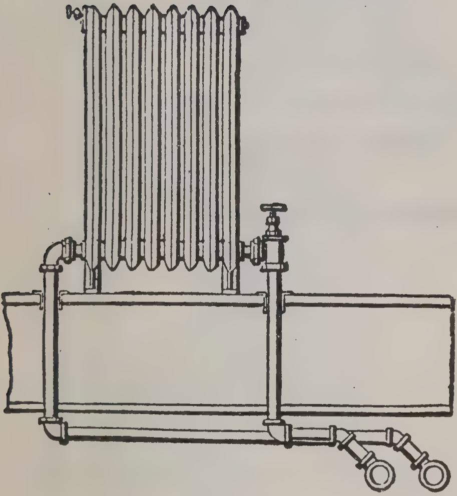


Fig. 13.

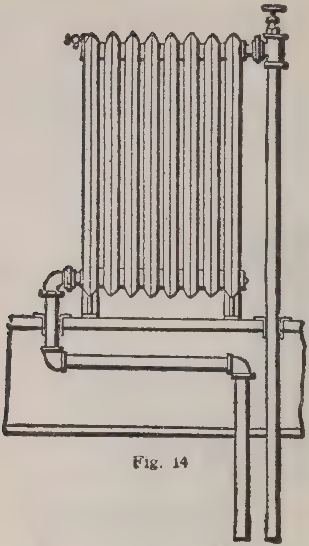


Fig. 14

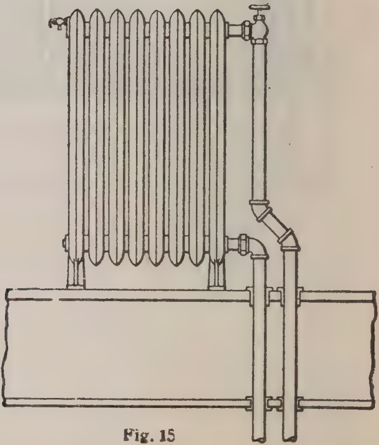


Fig. 15

Figures 16 and 17 Show Proper Methods of Connecting Hot Water Radiators From Overhead Systems. Air Valves Are Not Needed in Systems of This Kind.

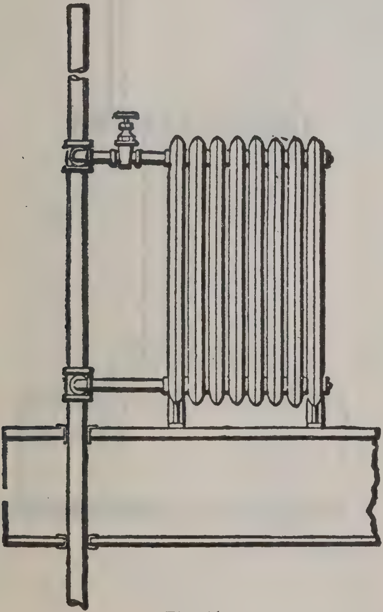


Fig. 16.

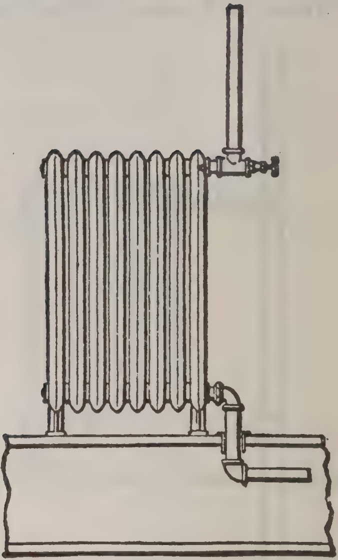


Fig. 17

Figures 18 and 19 Show Best Method of Constructing Hot Water Coils For 1 and 2 Pipe Systems.

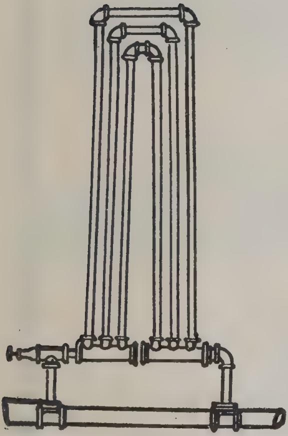


Fig. 18.

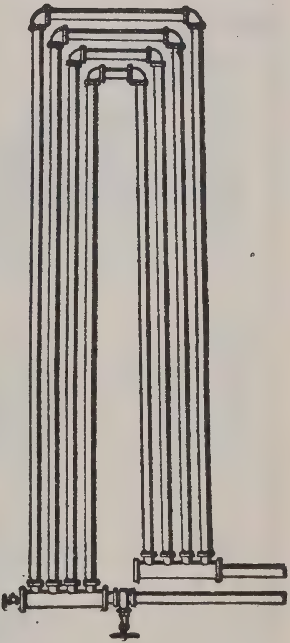
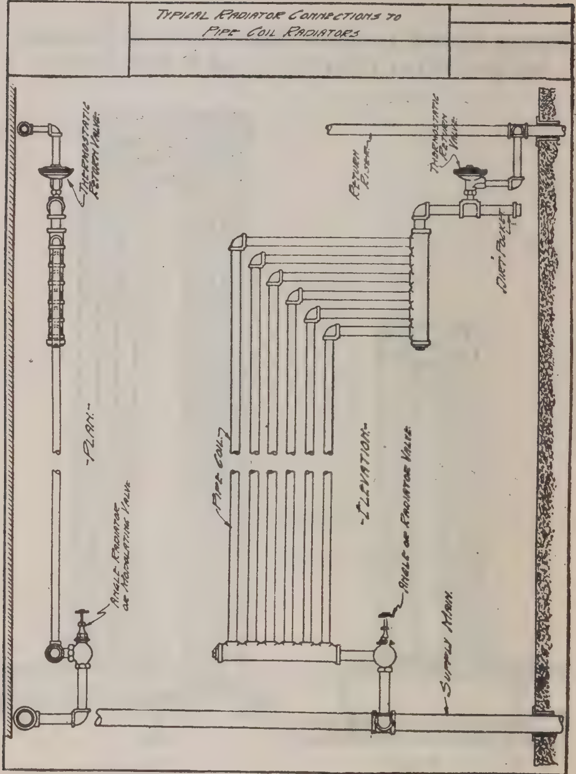


Fig. 19.


TYPICAL RADIATOR CONNECTIONS TO PIPE COIL RADIATORS
THERMOSTATIC RETURN VALVE
-PLAN-
ANGLE RADIATOR OR MODULATING VALVE
PIPE COIL
-ELEVATION-
ANGLE OR RADIATOR VALVE
SUPPLY MAIN
RETURN RISER
THERMOSTATIC RETURN VALVE
DIRT POCKET

G. C.

A few illustrations showing most successful methods of taking connections off mains and risers for hot water circulation, also showing branches connecting to radiators.

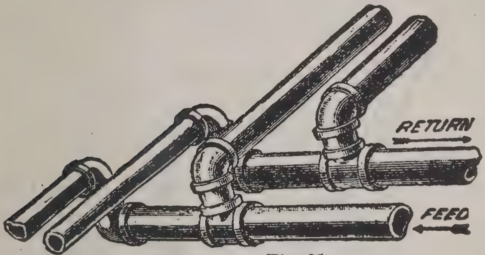

RETURN
FEED

Fig. 25.

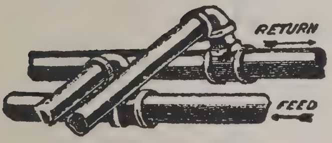

RETURN
FEED

Fig. 26.

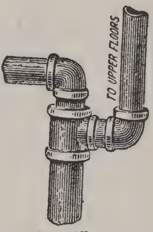

TO UPPER FLOORS

Fig. 27

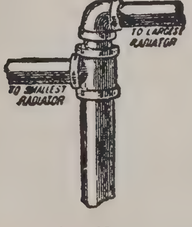
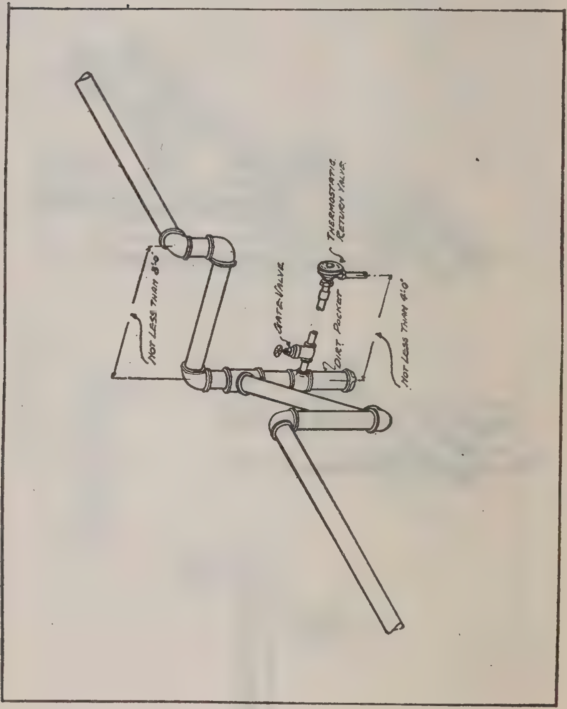

TO LARGEST RADIATOR
TO SMALLEST RADIATOR

Fig. 28.

METHOD OF DRIPPING SWING JOINT

Illinois System of Vacuum Heating


NOT LESS THAN 8'0"
GATE-VALVE
THERMOSTATIC RETURN VALVE
DIRT POCKET
NOT LESS THAN 4'0"

Tapping for Radiators.

One Pipe Work.

Less than 24 feet, 1 inch pipe.
Over 24 feet up to 50 feet, 1¼ inch pipe.
Over 50 feet up to 90 feet, 1½ inch pipe.
Over 90 feet up to 150 feet, 2 inch pipe.

Two Pipe Work.

Less than 30 feet, 1x¾.
30 to 60 feet, 1¼x1.
50 to 100 feet, 1½x1¼.
100 to 160 feet, 2 x1½.

Indirect Radiators.

30 to 50 feet, 1¼x1 inches.
50 to 100 feet, 1½x1¼ inches.
100 to 150 feet, 2 x1½ inches.

Hot Water Tapped for Supply and Return.

Radiators containing 40 square feet and under 1 -in.
Above 40, but not exceeding 72 square feet 1¼-in.
Above 72 square feet........................1½-in.

Figuring Radiation, Steam or Hot Water

Assume room to be heated is on the first floor and basement underneath is unheated except for steam pipes running on basement ceiling. This usually can be depended on to give a basement temperature of 40 degrees in zero weather unless the building is of unusually poor construction.

Assume that the room is underneath a second story room which is heated to the same temperature as the first story; also assume that the adjoining rooms are heated to the same temperature.

Then the heat loss from the room takes place through the outside walls, windows and floor only.

The room will require additional heat because the air is continually leaking out through cracks around windows, doors, fire places, etc., and through opening doors and windows.

First: Estimate the number of times the entire air contents of the room is likely to be changed per hour by this leakage. The following table may be used as a guide for this estimate:

Halls	2 to 3	Drug stores	3
Living rooms	2 to 3	Clothing stores	1
Dining rooms	1 to 2	Jewelry stores	1
Kitchens	2	Grocery stores	1 to 2
Bedrooms	2	Law offices	1
Sewing rooms	2	Doctors' offices	1 to 2
Second floor halls	1	Dentists' offices	1 to 2

The number of cubic feet of air per hour to be heated is found by multiplying the cubic feet contents of the room by the number of air changes. Look at the illustration (Fig. 21, page 67), and you will note a room 13'×15'×10', which equals 1950 cubic feet of space.

If we have decided on two air changes per hour, then we must heat 2×1950=3900 cubic feet of air from outdoor temperature to the room temperature. Let us take this as 70 degrees difference, which equals 70 degrees temperature in zero weather. (If figuring for 10 degrees below zero weather, the difference will be 80 degrees, and so on.) Because one heat unit (B. T. U. or U) is needed to raise 50 cubic feet of air 1 degree, we will use 1.4 heat units to heat 1 cubic foot of air 70 degrees, and 3900 cubic feet will require 3900×1.4=5460 heat units (U).

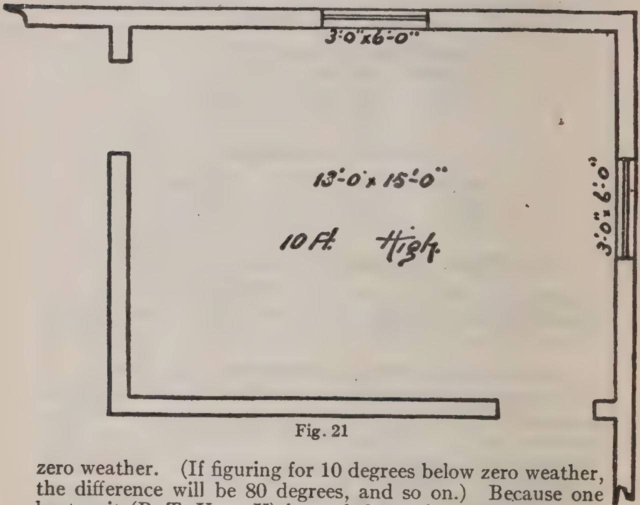


Fig. 21

The following table gives the heat units required for different weather conditions:

For 30 deg. difference in temperature, multiply each cu. ft. of air by .6.
For 40 deg. difference in temperature, multiply each cu. ft. of air by .8.
For 50 deg. difference in temperature, multiply each cu. ft. of air by 1.0.
For 60 deg. difference in temperature, multiply each cu. ft. of air by 1.2.
For 70 deg. difference in temperature, multiply each cu. ft. of air by 1.4.
For 80 deg. difference in temperature, multiply each cu. ft. of air by 1.6.
For 90 deg. difference in temperature, multiply each cu. ft. of air by 1.8.

Again looking at the illustration (Fig. 21, page 67), you will note that heat will be lost through both outside walls and windows.

13'+15'=28'×10'=280 sq. ft.
2 windows at 3'×6'=36 sq. ft. glass.

280−36=244 sq. ft. net wall.

The following table gives the heat units lost in one hour for each square foot of exposure of different materials used in buildings:

Type of Construction	30	40	50	60	70	80	90	100
Single window (good)	34	45	59	67	75	86	98	110
Single window (average)	36	48	61	73	86	98	110	123
Single skylight	30	41	52	63	73	83	94	105
Double skylight	18	24	30	37	43	49	55	62
Double window	22	30	36	42	51	59	66	72
Plate glass (set tight)	23	31	37	43	52	60	67	75
8″ brick wall	14	18	23	27	32	36	41	46
Door (½ glass)	17	22	28	34	40	45	51	57
Plain door	12	16	20	24	28	32	36	40
12″ brick wall	9	13	16	19	22	25	28	31
16″ brick wall	8	10	13	15	18	21	23	26
20″ brick wall	7	9	11	13	15	18	20	23
24″ brick wall	5	7	8	10	13	15	18	21
30″ brick wall	4	5	7	9	11	13	15	18
36″ brick wall	3	4	6	7	8	9	11	13
8″ brick wall, 3″ air space	9	11	14	17	20	24	27	30
12″ brick wall, 3″ air space	8	10	13	15	18	22	25	28
16″ brick wall, 3″ air space	6	8	10	13	16	19	22	25
12″ sandstone wall	16	20	25	28	31	34	37	41
16″ sandstone wall	15	18	21	24	27	30	32	35
20″ sandstone wall	13	15	18	22	25	28	30	33
24″ sandstone wall	8	12	15	18	21	24	26	29
32″ sandstone wall	9	11	14	16	19	22	25	27
36″ sandstone wall	7	9	12	15	17	19	21	24
44″ sandstone wall	5	8	10	12	14	16	18	20
12″ limestone wall	18	22	26	30	34	38	41	44
16″ limestone wall	14	18	22	26	30	34	38	40
20″ limestone wall	15	19	22	25	28	30	33	35
24″ limestone wall	12	14	18	21	24	27	30	33
28″ limestone wall	9	13	16	19	22	25	28	31
36″ limestone wall	8	11	14	16	19	21	24	27
44″ limestone wall	7	9	12	14	16	18	20	22
1½″ pine plank	8	12	15	18	21	24	27	30
2″ pine plank	8	10	13	16	18	20	22	24
2½″ pine plank	7	9	11	14	16	18	20	22
3″ pine plank	5	8	10	12	14	16	18	20
Sheathing and clapboards	12	14	16	18	20	22	24	26
Sheathing, paper and clapboards	8	10	12	14	16	18	20	22
Lath and plaster partition (1 side)	13	20	23	25	28	32	36	40
Lath and plaster partition (both sides)	10	13	16	19	22	25	28	31
Lath and plaster ceiling (1 side)	18	20	22	25	28	32	36	40
¾″ floor, no plaster below	13	16	19	22	25	28	31	34
¾″ floor, lath and plaster below	8	10	13	16	19	22	25	28
1½″ double floor, no plaster	9	11	14	17	20	23	25	27
1½″ double floor, lath and plaster below	5	7	9	11	13	15	17	19
Average frame	15	18	21	24	26	28	31	33
Average frame, back plastered	14	17	20	22	24	26	28	30
Average red brick, back plastered	14	17	20	22	24	26	28	30

If we have good window construction, single sash, you will find (under column 70) 75 heat units (U) loss for each square foot in one hour. Then 36×75=2700 heat units lost through the glass.

If we have average frame construction, you will find (under column 70) 26 heat units loss for each square foot in one hour. Then 244×26=6344 heat units lost through the walls.

We have 195 sq. ft. of floor which will lose heat from the room (70 deg. temperature) to the basement (40 deg. temperature) at the rate due to 30 degrees difference.

If we have 1½-inch double floor without plaster you will find (under column 30) 5 heat units loss for each square foot in one hour. Then 195×5=975 heat units lost through the floor.

Our heat loss calculation now looks like this:

13×15×10=1950×2×1.4= 5460 U
13+15=28×10=280
2×3×6= 36×75 = 2700 U
244×26 = 6344 U
13×15=195×5= 975 U
Total heat loss= 15479 U

If the room is very badly exposed, say on the northwest corner of the building, or if subjected to high winds, it is well to add at least 10 per cent to the heat loss.

After determining the total heat loss per hour, the amount of radiation necessary to overcome that loss is found by dividing the total by the number of heat units which each square foot of the radiator intended to be used is capable of delivering. The usual figures are as follows:

Low pressure steam radiators	250 U
Atmospheric or vapor radiators	200 U
Hot water radiators	170 U

Thus if the above room is on a northwest corner and we will use the atmospheric system, our final figures are:

15479 U
Plus 10% 1548
200)17027 U
85 sq. ft.

which may be 17 sections or loops of 3 column 38″ radiation of any standard make or which may be arranged otherwise if more convenient.

Indirect Radiation

To get the proper amount of indirect radiating surface for low pressure steam heating, 50% more surface is necessary than where direct surface is used, so that to warm the room, under above conditions, by indirect radiation 102 square feet of radiation would be required.

Vertical and Horizontal Tank.

Capacity, Gallons.	Diameter, Inches.	Length, Feet.	Approximate Weight.
66	18	5	220
85	20	5	250
100	22	5	280
120	24	5	320
145	24	6	360
170	24	7	400
180	30	5	480
215	30	6	540
250	30	7	590
300	30	8	640
325	36	6	780
365	36	7	810
420	36	8	880
430	42	6	1150
575	42	8	1400
720	42	10	1650

Air and Water Pressure Tanks.

Diameter, Feet.	Length Feet.	THICKNESS.		Weight.	Capacity, Gallons.
		Shell.	Heads.		
5	20	5/16	3/8	6250	2922
5	25	5/16	3/8	7390	3654
5	30	5/16	3/8	8580	4384
6	20	5/16	1/2	7800	4240
6	28	5/16	1/2	10200	5936
6	36	5/16	1/2	12450	7632
7	20	5/16	1/2	8600	5761
7	28	5/16	1/2	11100	8066
7	36	5/16	1/2	13600	10370
8	24	5/16	1/2	11800	8980
8	30	5/16	1/2	14000	11224
8	36	5/16	1/2	16200	13468

Tank Capacity.

Diameter.	Gallons per Foot of Depth.
2 feet	23.5
2 feet 6 inch	36.7
3 feet	52.9
3 feet 6 inch	72.0
4 feet	94.0
4 feet 6 inch	119.0
5 feet	146.9
5 feet 6 inch	177.7
6 feet	221.5
6 feet 6 inch	248.2
7 feet	287.9
7 feet 6 inch	330.5
8 feet	376.0
8 feet 6 inch	424.5
9 feet	475.9
9 feet 6 inch	530.2
10 feet	587.5
11 feet	710.9
12 feet	846.0
13 feet	992.0
14 feet	1151.5
15 feet	1321.9
20 feet	2350.1
25 feet	3672.0
30 feet	5287.7
35 feet	7197.1
40 feet	9400.3

Air and Water Pressure Tanks.

Diameter, Inches.	Length Feet.	Weight	Capacity, Gallons.
24	6	350	140
24	8	420	190
24	10	500	235
30	6	530	220
30	8	650	295
30	10	770	365
30	12	900	440
30	14	1000	515
36	6	750	315
36	8	900	420
36	10	1050	525
36	12	1200	630
36	14	1400	735
36	16	1575	840
42	8	1450	575
42	10	1650	720
42	12	1900	865
42	14	2200	1000
42	16	2400	1150
42	18	2650	1300
42	20	2900	1440
48	10	2200	940
48	12	2550	1130
48	14	2900	1300
48	16	3250	1500
48	18	3600	1700
48	20	3950	1880
48	24	4650	2260

Number of U. S. Gallons in Rectangular Tanks—For one foot in depth

Width of Tank	LENGTH OF TANK.																				
	2 ft.	2 ft. 6 in.	3 ft.	3 ft. 6 in.	4 ft.	4 ft. 6 in.	5 ft.	5 ft. 6 in.	6 ft.	6 ft. 6 in.	7 ft.	7 ft. 6 in.	8 ft.	8 ft. 6 in.	9 ft.	9 ft. 6 in.	10 ft.	10 ft. 6 in.	11 ft.	11 ft. 6 in.	12 ft.
2 ft.	30	37	45	52	60	67	75	82	90	97	105	112	120	127	135	142	150	157	165	172	180
2 ft. 6 in.		47	56	65	75	84	94	103	112	122	131	140	150	159	168	178	187	196	206	215	224
3 ft.			67	79	90	101	112	123	135	146	157	168	180	191	203	213	224	236	247	258	269
3 ft. 6 in.				92	105	118	131	144	157	170	183	196	209	223	236	249	262	275	288	301	314
4 ft.					120	135	150	165	180	194	209	224	239	254	269	284	299	314	329	344	359
4 ft. 6 in.						151	168	185	202	219	236	252	269	286	303	320	337	353	370	387	404
5 ft.							187	206	224	243	262	281	299	318	337	355	374	393	411	430	449
5 ft. 6 in.								226	247	267	288	309	329	350	370	391	411	432	453	473	494
6 ft.									269	292	314	337	359	381	404	426	449	471	494	516	539
6 ft. 6 in.										316	340	365	389	413	438	462	486	511	535	559	583
7 ft.											367	393	419	445	471	497	524	550	576	602	628
7 ft. 6 in.												421	449	477	505	533	561	589	617	645	673
8 ft.													479	509	540	569	598	628	658	688	718
8 ft. 6 in.														540	572	604	636	668	699	731	763
9 ft.															606	640	673	707	741	774	808
9 ft. 6 in.																675	711	746	782	817	853
10 ft.																	748	785	823	860	898
10 ft. 6 in.																		825	864	903	943
11 ft.																			905	946	987
11 ft. 6 in.																				989	1032
12 ft.																					1077

GRAVITY HOT WATER HEATING

Sizes of Mains for Basement **Two Pipe Non-Short Circuit System** where Mains are not over 100 ft. long.

1¼ inch pipe, 0 square feet to 100 square feet
1½ inch pipe, 101 square feet to 250 square feet
2 inch pipe, 251 square feet to 400 square feet
2½ inch pipe, 401 square feet to 650 square feet
3 inch pipe, 651 square feet to 1000 square feet
3½ inch pipe, 1001 square feet to 1900 square feet
4 inch pipe, 1901 square feet to 2500 square feet
4½ inch pipe, 2501 square feet to 3100 square feet
5 inch pipe, 3101 square feet to 4000 square feet
6 inch pipe, 4001 square feet to 5600 square feet

SIZES OF RISERS

¾ inch pipe, 0 square feet to 40 square feet
1 inch pipe, 45 square feet to 65 square feet
1¼ inch pipe, 70 square feet to 100 square feet
1½ inch pipe, 110 square feet to 150 square feet

SIZES OF VALVES

½ inch valve, 0 square feet to 40 square feet
¾ inch valve, 45 square feet to 65 square feet
1 inch valve, 70 square feet to 90 square feet
1¼ inch valve, 95 square feet to 120 square feet
1½ inch valve, 125 square feet to 165 square feet

Refer to page 108 for diagram showing **Two Pipe Non-Short Circuit System.**

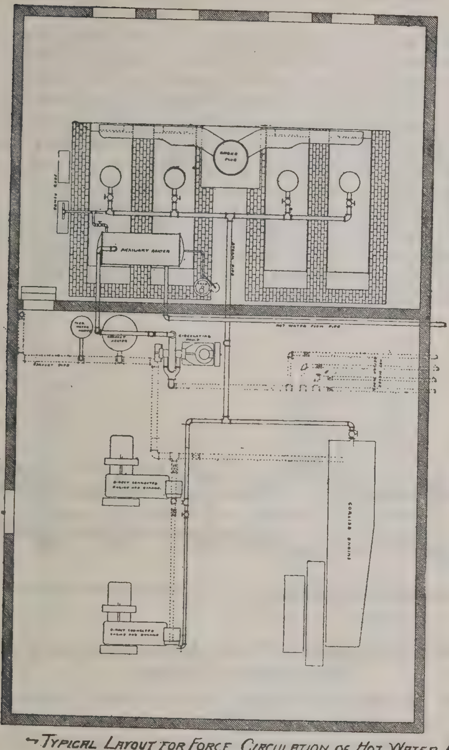
Forced Circulation Hot Water Heating.

In large systems of hot water heating, water is used as the heating medium, and is circulated through a system of supply and return mains, coils or radiators, which, with the exception of certain minor details, are quite similar to those used in steam heating practice. In a properly designed system, the supply and return mains are arranged so that the flow of water will be in the direction naturally induced by gravity, so that this force will assist as far as possible in producing circulation. A pump, usually of the centrifugal type, is placed in the circuit, by means of which positive and controllable circulation in all parts of the system is assured. Hence the term **"Hot Water Heating by Forced Circulation."**

Where there is a power plant, and exhaust steam is available for heating, the water of circulation is heated by passing through a tubular heater, similar to the closed type of feed water heater. In addition to the exhaust steam heater, an auxiliary heater, smaller in size, is also installed, for heating the circulating water with live steam, when the supply of exhaust steam is either insufficient or entirely lacking.

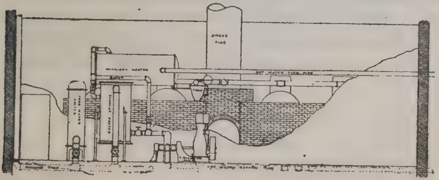
The circulating water, after leaving the pump, passes first through the heater, and thence into the main supply line. The velocity of flow is successively reduced as this main supply line separates into various branches and thence into connections to the heating surface, the sum total cross section area of these individual connections being much greater than the cross section area of the main as it leaves the heater. After slowly passing through the radiation units, so that ample time for giving up its heat is afforded, the water again gathers velocity through reduced total cross section area of mains until it passes into the inlet side of the pump, thereby completing the circuit.

An expansion tank, generally located at the highest point of the system, provides for expansion and contraction due to varying temperatures of water. This tank is provided with an overflow pipe and inlet pipe, the latter being controlled by an automatic water feeder which admits water to the system when the level in the tank goes below a certain point. All the water in the system circulates in a closed circuit, and the same water is used over and over again, no fresh water being admitted except to equalize the loss from


SMOKE FLUE
AUXILIARY HEATER
STEAM PIPE
TRAP
HOT WATER FLOW PIPE
FEED WATER HEATER
EXHAUST HEATER
CIRCULATING PUMP
EXHAUST PIPE
DIRECT CONNECTED ENGINE AND DYNAMO
DIRECT CONNECTED ENGINE AND DYNAMO
CORLISS ENGINE

POWER PLANT SHOWING EVANS EXHAUST-HOT WATER HEATING SYSTEM.

→ TYPICAL LAYOUT FOR FORCE CIRCULATION OF HOT WATER HEATING. →


SMOKE FLUE
AUXILIARY HEATER
HOT WATER FLOW PIPE
FEED WATER HEATER
EXHAUST HEATER
TRAP

leakage and overflow from expansion tank. Consequently, the circulating pump does not work any **static head,** as the static head is the same on both inlet and outlet, but only against a **friction head,** and all work which it performs is used in overcoming the friction of water in passing through the system.

It is the advantages of **"hot water heating by forced circulation"** as compared to **"vacuum steam heating"** that this article is intended to demonstrate. In doing this it will be our endeavor to avoid any highly colored statements, presenting only facts. stated simply, and in such a way as to permit of their being checked by the good judgment of architects, engineers, manufacturers, and others who may be interested in this subject.

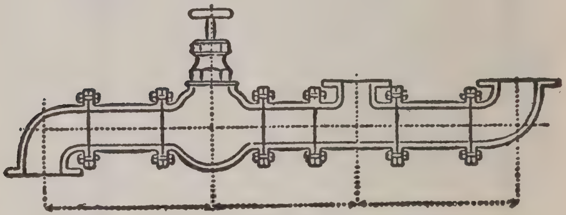


Fig. 20

How to Properly Take Measurements of Pipes and Fittings

In Fig. 20, we give a diagram of two elbows, a valve, and a tee, with lines drawn through the center of each fitting, also a lateral line below with arrows indicating the center points of fittings, inside of which the measurements are to be marked. This makes it clear when ordering pipe work with fittings cut to order, so that if the measurements are correctly taken and placed on diagram, there can be no mistakes in getting out such work.

Overhead System of Hot Water Heating Apparatus.

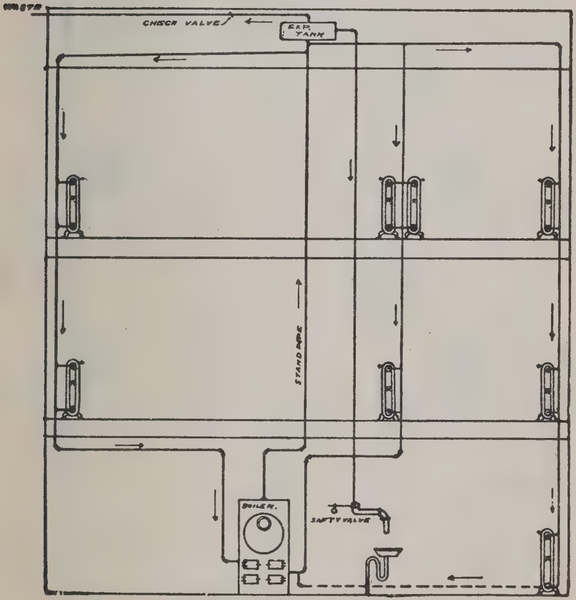

WASTE
CHECK VALVE
EXP. TANK
STAND PIPE
BOILER.
SAFETY VALVE

Fig. 1.

Single Pipe Hot Water System.

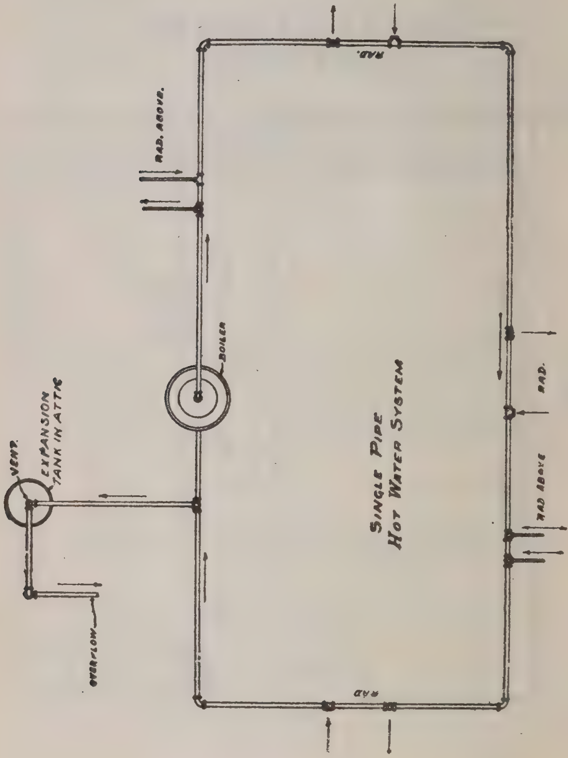

RAD.
RAD. ABOVE.
BOILER
VENT.
EXPANSION TANK IN ATTIC
OVERFLOW
SINGLE PIPE HOT WATER SYSTEM
RAD.
RAD ABOVE
RAD

Fig. 2.

Overhead Open Hot Water System.

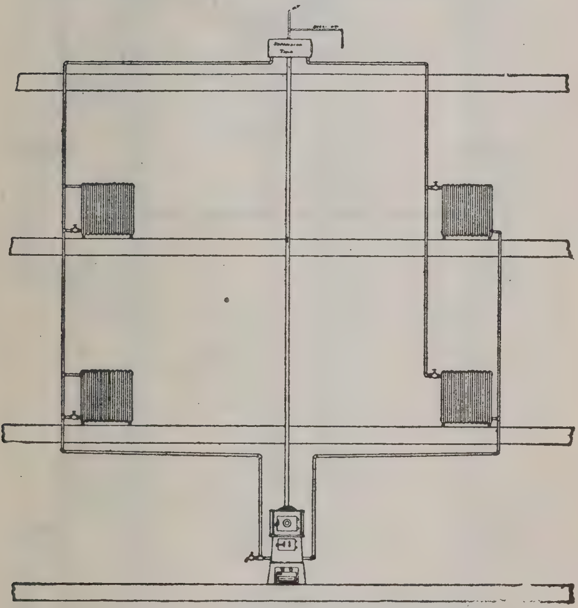
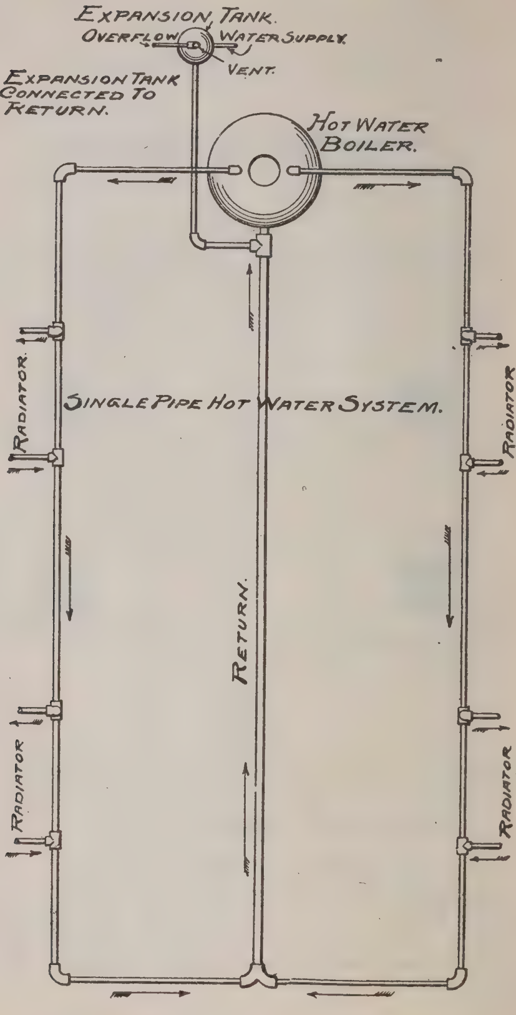
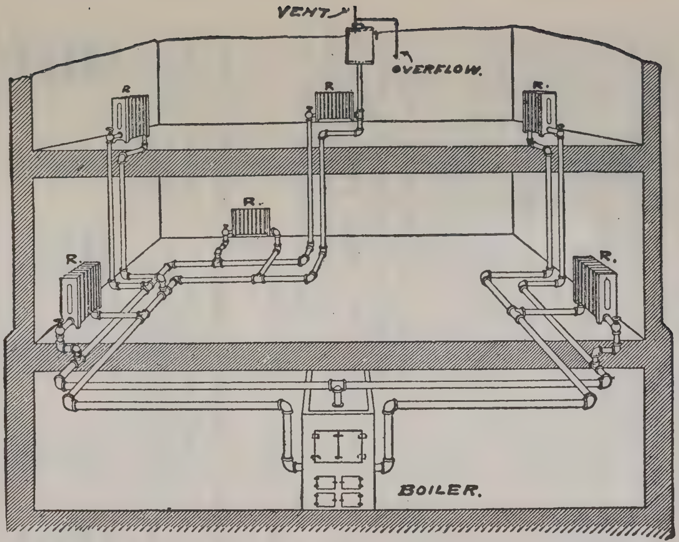


Fig. 3.

Single Pipe Hot Water System.

Ordinarily there should be a twin ell, used on top of the boilers to branch each way, and use sweep fittings. This will make a perfect system of hot water heating, and do away with so many pipes in the basement.


EXPANSION TANK.
OVERFLOW
WATER SUPPLY.
VENT.
EXPANSION TANK CONNECTED TO RETURN.
HOT WATER BOILER.
RADIATOR.
SINGLE PIPE HOT WATER SYSTEM.
RADIATOR
RETURN.
RADIATOR
RADIATOR


VENT
OVERFLOW.
R
R
R.
R.
R.
R.
BOILER.

TWO PIPE HOT WATER SYSTEM.

Connecting Expansion Tanks for Hot Water Open Tank System

In Fig. 23 is shown the correct method of connecting the expansion tank for a hot water heating system. The supply "A" to the tank should be taken from the return pipe "B" from the radiator, and not from the supply to the radiator. The pipe "C" is an overflow from the tank, and should be carried to the closet tank, or to some other open fixture. The pipe "D" is the vent and is merely to prevent syphonage, but should always be put in and carried not less than 6″ above the overflow pipe.

In Fig. 24 is shown an expansion tank similar to Fig. 23 except that the tank is circulated to prevent freezing. The supply and return pipes are taken from the risers below the floor in order that the tank will interfere as little as possible with the proper working of the radiator.

Amount of Radiation Expansion Tank Will Carry.

Size, Inches.	Capacity, Gallons.	Sq. Ft. of Radiation.	Size, Inches.	Capacity, Gallons.	Sq. Ft. of Radiation.
10x20	8	250	16x36	32	1300
12x20	10	300	16x48	42	2000
12x30	15	500	18x60	66	3000
14x30	20	700	20x60	82	5000
16x30	26	950	22x60	100	6000

Expansion Tanks.

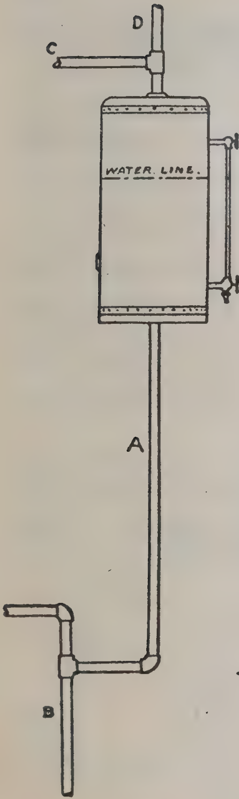

D
C
WATER LINE.
A
B

Fig. 23.

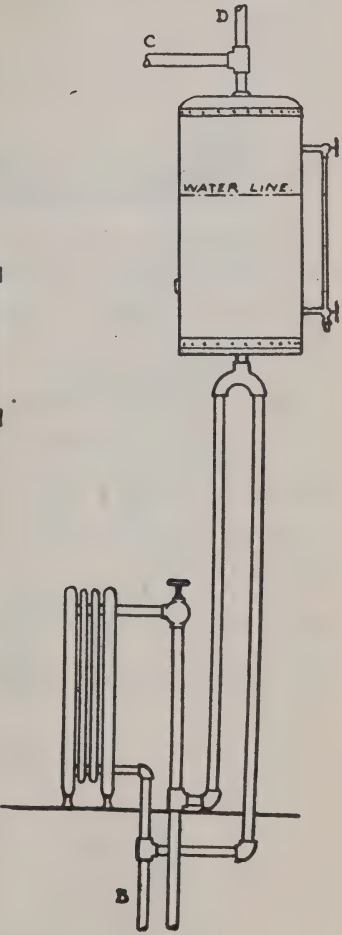

D
C
WATER LINE.
B

Fig. 24.

How to Construct Long Horizontal Flow Mains in Hot Water Heating Plants.

In constructing hot water heating plants for scattered buildings, where all radiation is supplied from one boiler or a group of boilers coupled together, there must be some careful calculations made in the laying out of pipe work in order to secure a good circulation at all points throughout the plant. And, for the purpose of showing how this can be done in a successful manner, we make use of plate Fig. A, which is the working drawing of a large hot water heating plant now in operation and giving the most satisfactory results.

We merely show in plate Fig. A the cellar mains connected to the boiler, but branches are taken from top of flow lines to the various radiators and risers with returns carried back to side of same flow lines.

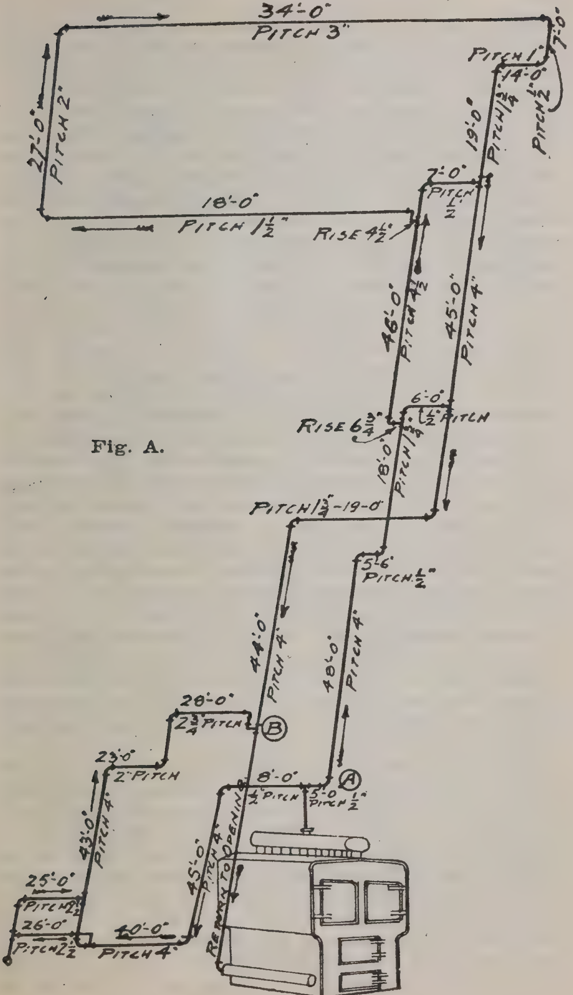

34'-0"
PITCH 3"
7'-0"
PITCH 1"
14'-0"
PITCH 1/2"
27'-0"
PITCH 2"
19'-0"
PITCH 1 3/4"
7'-0"
PITCH 1/2"
18'-0"
PITCH 1 1/2"
RISE 4 1/2"
46'-0"
PITCH 4 1/2"
45'-0"
PITCH 4"
6'-0"
1/2" PITCH
RISE 6 3/4"
18'-0"
PITCH 1 3/4"
PITCH 1 3/4"-19-0"
5'-6"
PITCH 1/2"
44'-0"
PITCH 4"
48'-0"
PITCH 4"
28'-0"
2 3/4" PITCH
B
23'-0"
2" PITCH
8'-0"
1/2" PITCH
A
5'-0
PITCH 1/2"
43'-0"
PITCH 4"
45'-0"
PITCH 4"
RETURN TO OPENING
25'-0"
PITCH 2 1/2"
26'-0"
PITCH 2 1/2"
40'-0"
PITCH 4"

Fig. A.

Referring to the plan, it will be observed that the main flow from boiler connects with a Tee which separates the flow water to each side of the boiler as it is located. This Tee is the highest point in the cellar system of main pipes. We will now follow the flow line of the right, marked (A). The direction of the arrow will show the direction in which the water moves. The first Tee over the boiler being the highest point, we begin to pitch down from this point, and, as will be noticed, in a distance of 5 feet we have a fall of ½ inch to the first angle or elbow. We have now a run of 48 feet, and in this distance we pitch down 4 inches. We now come to a bend in the line which is 5 feet 6 inches long and we give this a ½ inch pitch. The next long stretch is 18 feet, which is given 1¾ inch pitch. At this point we place a Tee on the line with the outlet looking up, with the end of this Tee connecting by a 6 foot piece of main pipe to the side of the return, as shown. This offset is pitched ½ inch, which practically completes the first circuit.

It will now be noticed as far as we have gone with this main flow line to the first Tee looking up, we dropped 6¾ inches, and to continue further horizontally we rise from top of Tee just described, the same distance which we pitched down from boiler, 6¾ inches, then extending the main flow line, as will be noticed, a distance of 46 feet more, with a pitch in this distance of 4½ inches, connecting with another Tee, we rise again the distance which we dropped in the last run, which is 4½ inches, and, connecting the end of Tee to the side of return pipe, thus completing a second circuit in the main lines.

The main flow line is pitched down again from the last 4½ inch rise as indicated, making the last circuit on the extreme end of the system and gradually pitching back to the return connectiton of boiler. (B) represents the main return pipe in the system, and, referring again to the pipe work on the left of boiler, the same general method is carried out, forming separate circuits according to the distance and conditions of the building yet with only one flow and one return pipe connecting with the boiler. It is advisable to place air valves or air pipes at all high points on main flow lines, so that any air that may accumulate at such points, can be drawn or allowed to escape.

This system of dividing the main flow line into various circuits gives a more uniform distribution of the hot water to the radiation, and allows the coldest water in the system to move back more rapidly to the boiler, by not having to travel the entire distance of the flow line.

In pipe systems as shown in Fig. A, the proportioning of the size of the pipes at the various points for the work to be performed, is also an important matter, and long sweep fittings only should be used.

Rapid Circulation of Hot Water.

A simple manner of illustrating friction in the flow of water through pipes at various angles is shown in the accompanying illustration, which represents 5 pipes standing on end. If we drop a marble into each pipe, and take notice of the time that it take the marble to travel through each pipe we will find that the marble dropped into the straight pipe will reach the bottom in the shortest time. The marble dropped into the quarter bend pipe, Fig. 5, will require the longest time. If these pipes were of glass we would notice—we will say for illustrating it—that the marble dropped into the straight pipe, marked Fig. 1, would travel through this straight and perpendicular pipe without touching the wall of the pipe—as shown by arrows in illustration—consequently no friction. In Figure Fig. 2 it would drop at a great velocity through the straight part, which is about ⅔ of the whole length of the pipe, but as soon as it reaches the bent part it would roll on the wall of the pipe, causing a friction which would retard its motion. In Figure 3 the straight and perpendicular part of the pipe is

Rapid Circulation of Hot Water

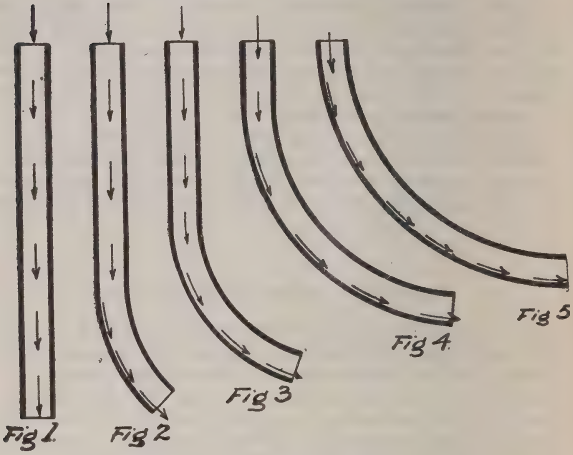


Fig. B.

less than in Fig. 2, and in Fig. 4 it is less than in Fig. 3, therefore the marble will be under frictional contact of the pipe for a longer time in Fig. 3 than it is in Fig. 2, and in Fig. 4 far more than it is in Fig. 3. Fig. 5 being a quarter bend, the marble will come in contact with the pipe from the very starting point. Consequently be under friction through its whole journey through the pipe, and requiring the longest time to pass through it. This might represent an elbow in a hot water heating plant. Short Elbows and Bends, therefore, for such work are great obstacles to rapid movement of water in any heating apparatus. Long Bends should be used where angles are necessary, in branches as well as in elbows.

Greenhouse Heating System.

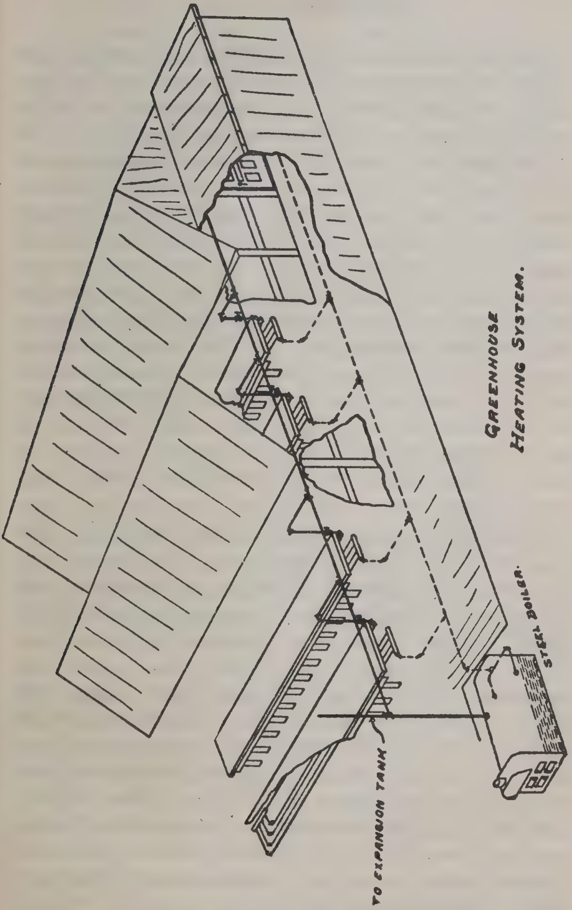

GREENHOUSE HEATING SYSTEM.
STEEL BOILER.
TO EXPANSION TANK

Fig.41.

Greenhouse Heating.

A glass structure for horticultural purposes (owing to the manner of its construction and the materials employed) offers less resistance to the penetration of frost and cold winds than any other form of building, and necessarily requires a proportional greater amount of heat and its more even distribution. To warm such a structure properly, without imparing the quality of the air, the heat must be produced by direct radiation from an extended surface heated to a moderate degree. The heating apparatus must be so arranged as to diffuse an even heat throughout every part of the house, and must be of sufficient heating power to increase the heat quickly in case of sudden changes in the weather, and to maintain the desired temperature during the nights, when the fires are unattended. Of the various systems that have been advanced to meet these requirements, there are but three that have met with approval in general use; these I name in their order of excellence. First in the order of efficiency and economy is the system of heating by the circulation of hot water through iron pipes ranged round the house; these pipes are connected to a boiler or water heater, which heats the water and maintains the circulation through the pipes; the radiation from the pipes supplies the warmth to the house. This is the best method known for the purpose; the facility with which water absorbs the heat produced at the boiler, and by circulation, rapidly conveys it to the most distant points in the line of heating pipes, renders it a most efficient agent and affords the means of maintaining a uniform, even temperature of any required degree throughout all parts of the house; with a mild and humid atmosphere, which is congenial to the healthy growth and perfection of plants, flowers and fruits, while the substantial, enduring and reliable qualities of the apparatus, the easy managements and perfect control of heat in the house, or in several houses heated by the same fire, the number of hours it may be left without attention, and the entire freedom from deleterious gases, dust and smoke, are among the advantages fairly claimed for the system.

It is so universal in its application, and offers so many advantages over every other system, that it is generally adopted, both here and in Europe, for heating plant houses of every size and description, from the small home conservatory to the largest botanical structures, and will be found in use, to the exclusion of all other methods, in the establishments of the most prominent and successful horticulturists throughout the country.

How to Figure Heating Surface of a Greenhouse.

In figuring a greenhouse we have to deal entirely with exposed surface, cubic contents, rarely, if ever, being taken into account; therefore, the entire amount of glass exposed and its equivalent should be determined, and in doing this the ends and side walls should be figured just as surely as the overhead and end glass. The sides and end walls, if of wood, sheathed and papered good and tight, should be figured in the following proportions, viz: Five square feet of wall to one square foot of glass.

After obtaining the number of square feet of glass and equivalent, the next point is the proper amount of heating surface necessary, and this is dependant upon the temperature required in the greenhouse. The following proportions of glass to heating surface will be found fully accurate.

	St.	H.W.
To a temperature of 40° divide No. sq. ft. of glass by	9	6
To a temperature of 45° divide No. sq. ft. of glass by	8	5
To a temperature of 50° divide No. sq. ft. of glass by	7	4
To a temperature of 55° divide No. sq. ft. of glass by	6½	3¾
To a temperature of 60° divide No. sq. ft. of glass by	6	3½
To a temperature of 65° divide No. sq. ft. of glass by	5½	3¼
To a temperature of 70° divide No. sq. ft. of glass by	5	3

The above is based on an outside temperature of zero.

Lubricating System.

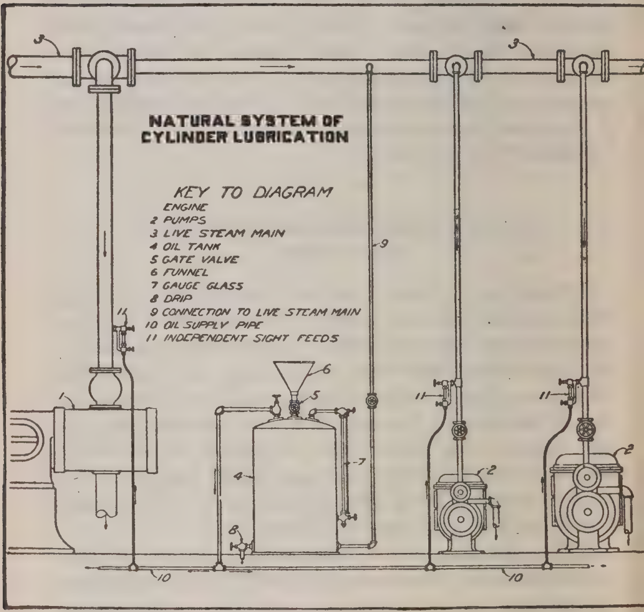
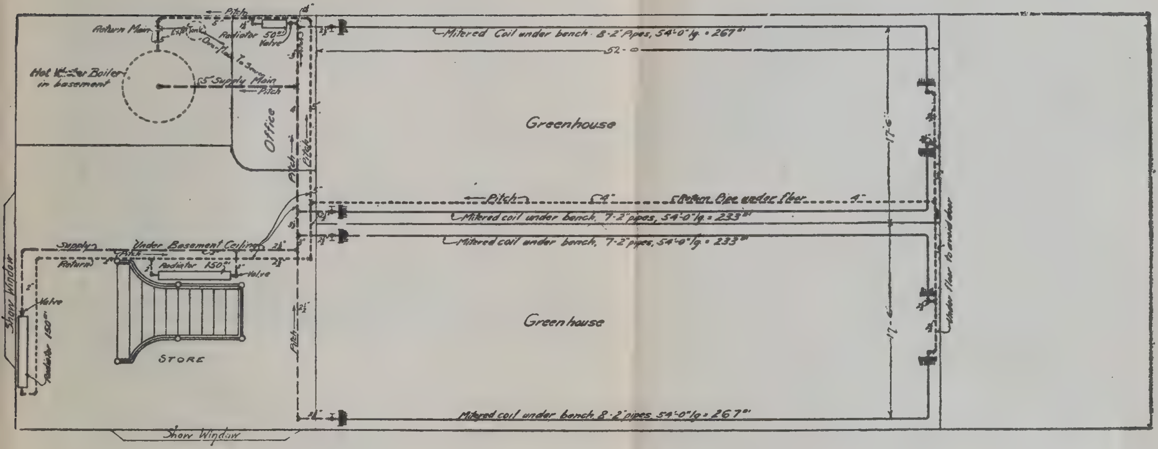
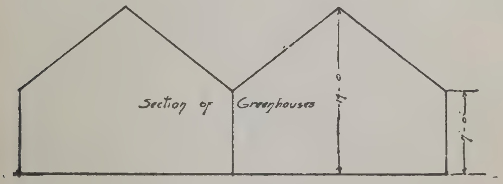

NATURAL SYSTEM OF CYLINDER LUBRICATION
KEY TO DIAGRAM
ENGINE
2 PUMPS
3 LIVE STEAM MAIN
4 OIL TANK
5 GATE VALVE
6 FUNNEL
7 GAUGE GLASS
8 DRIP
9 CONNECTION TO LIVE STEAM MAIN
10 OIL SUPPLY PIPE
11 INDEPENDENT SIGHT FEEDS
3
3
9
11
11
11
6
5
1
7
4
2
2
8
10
10

Fig. 39.


Pitch
Return Main
5"
Exp. Tank
Radiator 50
Valve
Over-flow To Sewer
Hot Water Boiler in basement
5" Supply Main
Pitch
Office
Pitch
Mitered Coil under bench 8-2" Pipes, 54'-0" lg. = 267
52'-0"
Greenhouse
17'-6"
Pitch
4"
Return Pipe under floor
4"
Mitered coil under bench, 7-2" pipes, 54'-0" lg. = 233
Mitered coil under bench, 7-2" pipes, 54'-0" lg. = 233
Supply
Under Basement Ceiling
2½"
Pitch
Return
Radiator 150
Valve
Show Window
Valve
Radiator 150
2"
STORE
Pitch
2½"
Greenhouse
17'-6"
Under floor to avoid door
Mitered coil under bench 8-2" pipes 54'-0" lg. = 267
Show Window


Section of Greenhouses
17'-0"
7'-0"

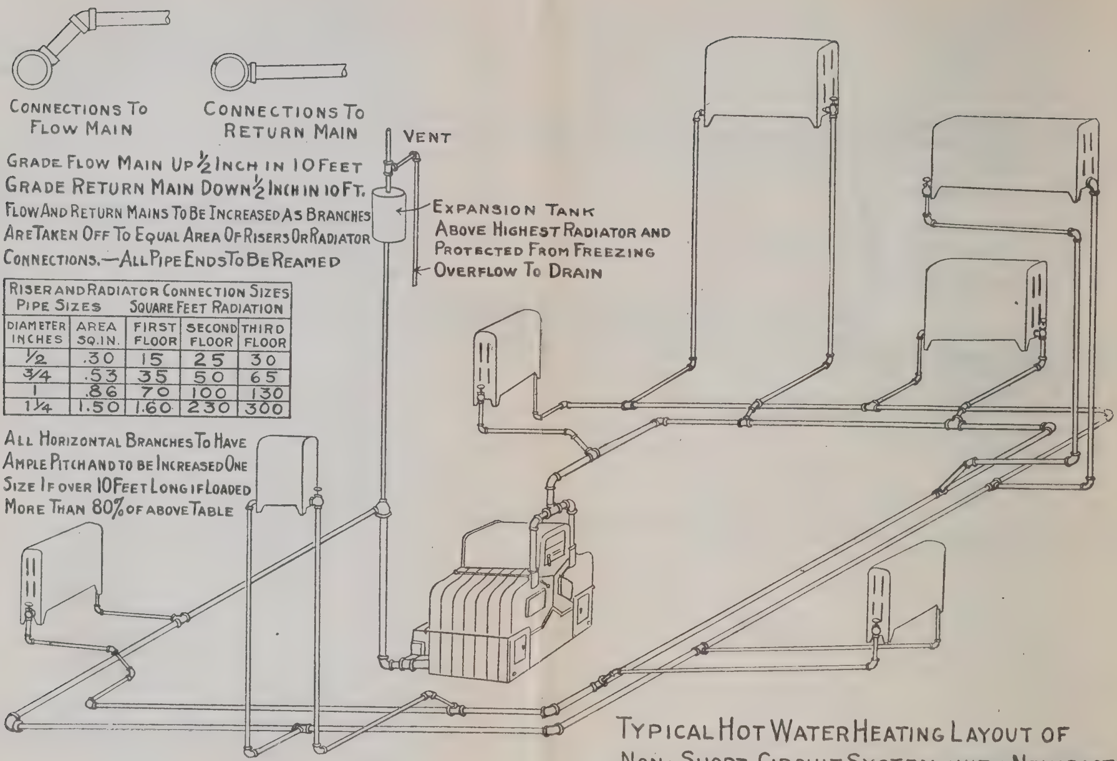
HEATING PLAN OF GREENHOUSE

—By—

JOHN W. JOHNSON

802 STEWART BLDG. CHICAGO, ILL

Scale-⅛"=1 Ft


CONNECTIONS TO FLOW MAIN
CONNECTIONS TO RETURN MAIN
VENT
EXPANSION TANK ABOVE HIGHEST RADIATOR AND PROTECTED FROM FREEZING
OVERFLOW TO DRAIN

GRADE FLOW MAIN UP ½ INCH IN 10 FEET
GRADE RETURN MAIN DOWN ½ INCH IN 10 FT.
FLOW AND RETURN MAINS TO BE INCREASED AS BRANCHES ARE TAKEN OFF TO EQUAL AREA OF RISERS OR RADIATOR CONNECTIONS.—ALL PIPE ENDS TO BE REAMED

RISER AND RADIATOR CONNECTION SIZES

PIPE SIZES		SQUARE FEET RADIATION		
DIAMETER INCHES	AREA SQ. IN.	FIRST FLOOR	SECOND FLOOR	THIRD FLOOR
½	.30	15	25	30
¾	.53	35	50	65
1	.86	70	100	130
1¼	1.50	1.60	230	300

ALL HORIZONTAL BRANCHES TO HAVE AMPLE PITCH AND TO BE INCREASED ONE SIZE IF OVER 10 FEET LONG IF LOADED MORE THAN 80% OF ABOVE TABLE

TYPICAL HOT WATER HEATING LAYOUT OF NON-SHORT CIRCUIT SYSTEM WITH NEWPORT AUTOMATIC FEED BOILER, RECOMMENDED BY AUTHOR TO SAVE 30 TO 50 PER CENT ON FUEL, BECAUSE PEA AND BUCKWHEAT COAL CAN BE USED AT A LOWER PRICE PER TON

Combination Hot Water and Warm Air Heating.

The advantages attending the combination system of heating, in supplying fresh warm air through the registers and circulating hot water through radiators for warming large and fine residences are portrayed to advantage in a description of an equipment of which a design is shown on the following page.

Considerable experimenting in the shape of balancing the heaters with the radiators has been done during the past 15 years. This type of furnace has overcome this difficulty.

This system not only accomplishes all that the expensive "indirect" steam or hot water system does, but goes further, in that it keeps the air warm in the rooms with the hot water radiators after we have sent into the rooms pure outside air thoroughly warmed by the furnace.

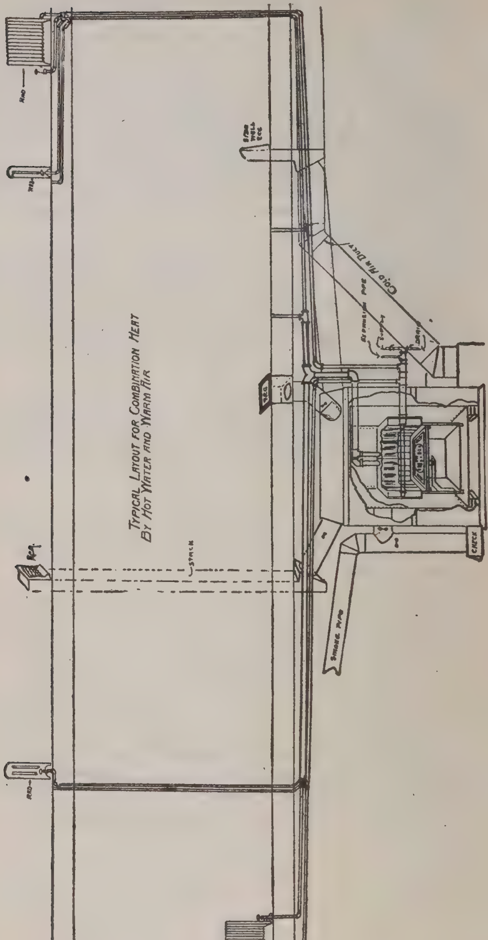
This constant forcing of pure air into the rooms and with the aid of the radiators produces a circulation which forces the warm air in every corner of the house, thus maintaining an even temperature throughout.

Ventilation, too, is taken care of by this perfect system of heating; the air is constantly changing and moving and as it is all thoroughly warmed before entering the rooms, there is no draft created.

There is a great advantage in using the combination system in mild weather, as the air is warmed from the furnace before the water gets hot and you do not have to run so heavy a fire.

With straight hot water heating, it requires some time to get the water hot and circulating, while with steam it is the same, as it takes quite a fire to raise steam. With all hot water plants it takes the water a long time to cool after it is warmed, which keeps the house overheated at times. We believe by combination system, from 15 to 25 per cent can be saved in fuel.

The Duplex Hot Water Heater, as shown in illustration, is the fire pot; it takes the place of the brick and is made in various sizes, suitable to take care of amount of radiation required. They will heat from 50 feet to 850 square feet of direct radiation. The water heaters practically represent a hot water boiler



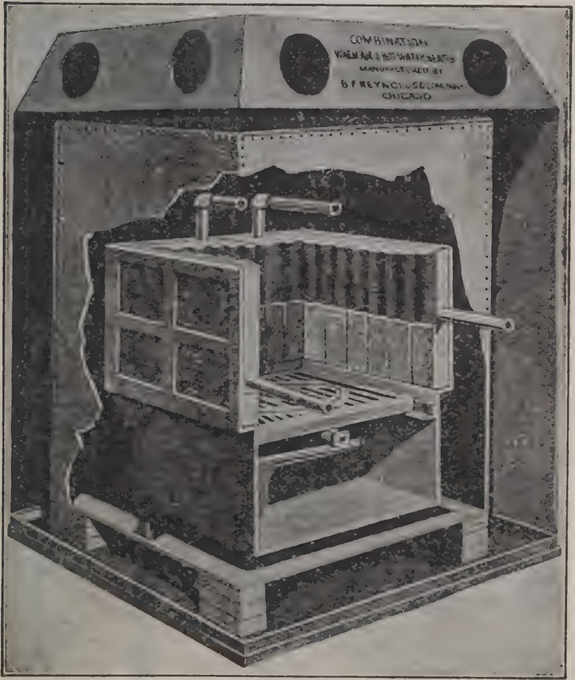
TYPICAL LAYOUT FOR COMBINATION HEAT BY HOT WATER AND WARM AIR

RAD
RAD
REG
STACK
RAD
STAIR WELL ETC
COLD AIR DUCT
EXPANSION PIPE
SUPPLY
DRAIN
REG
CHECK
SMOKE PIPE

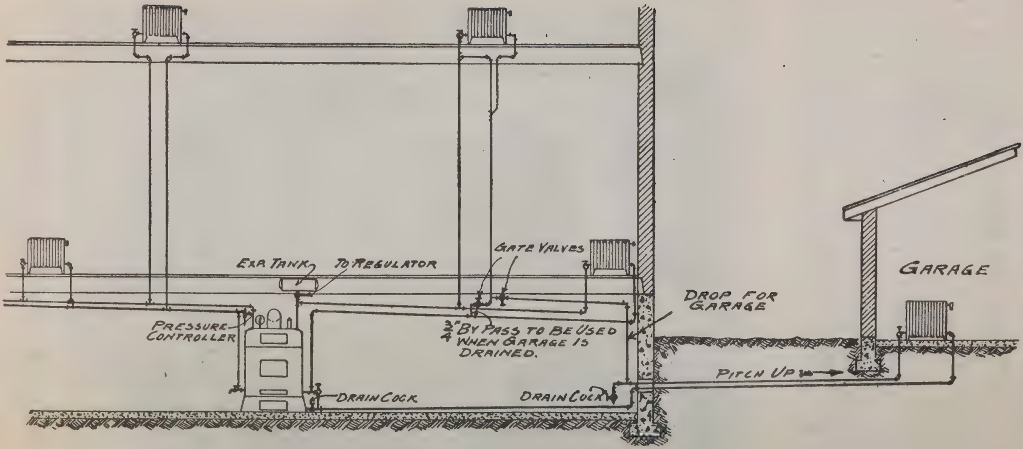
in a warm air furnace. One square foot of surface of the hot water heater will heat 50 square feet of direct hot water radiation.

Estimate about one-half of the amount of radiation when warm air is admitted in the same room. The radiator will temper the air, thus increasing the flow of warm air from the registers.

Place radiators in distant and large rooms, especially where a large amount of glass is located, rooms that cannot be reached easily by warm air, also those most exposed.


COMBINATION
WARM AIR & HOT WATER HEATERS
MANUFACTURED BY
B F REYNOLDS & COMPANY
CHICAGO

This is the most reliable furnace for combination heat, by hot water and warm air.


EXP. TANK
TO REGULATOR
GATE VALVES
PRESSURE CONTROLLER
3/4" BY PASS TO BE USED WHEN GARAGE IS DRAINED.
DROP FOR GARAGE
GARAGE
PITCH UP
DRAIN COCK
DRAIN COCK

D & T. SYSTEM.

—METHOD OF CONNECTING RADIATORS IN GARAGE—

—FROM BOILER LOCATED IN RESIDENCE.—

D. & T. SYSTEM OF HOT WATER HEATING

By using the D. & T. system of hot water heating smaller pipes can be used than in ordinary hot water heating. This system is very economical. Another good point is that both supply and return pipes between the house and garage are placed under ground, the boiler in the house supplying the heat to the garage. The D. & T. system is a sealed system, and a higher temperature can be produced than with an open tank system. In fact, the temperature of the water is almost equal to that of a steam heating system.

This system is highly recommended by the author.

MODERN VACUUM AND VAPOR SYSTEMS

Courtesy of American District Steam Company

This system uses steam at a very low pressure. Each radiator has a graduated valve placed at the top which permits only enough steam to pass to *partly* fill the radiator.

The amount of heat in the room is varied to suit the occupant by operating the valve, or by changing the steam pressure in the main. The radiators and return pipes are open to the atmosphere at all times through an open vent pipe, hence the system's name—"ATMOSPHERIC."

The greatest boiler pressure required is one-half pound in the coldest weather. The usual operating pressure is five ounces at the radiator valve. Under this pressure the steam flows into the radiator and expands in the top to atmospheric pressure. Here it loses its heat and trickles down the inside of the radiator as water. Further heat is given up, until the water falls out of the radiator return pipe only luke warm.

The air falls out of the same return pipe into the return and escapes through the open vent.

Only direct radiators having inside passages both at the top and the bottom (hot water type) should be used.

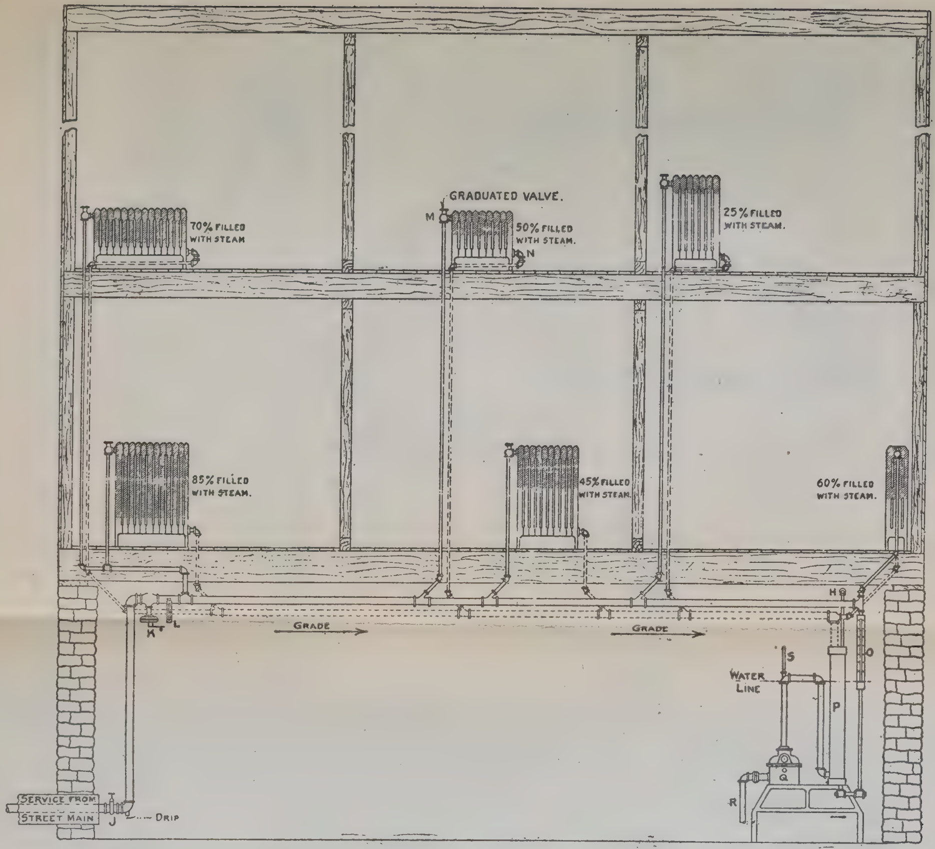
The graduated valve should not be used on indirect radiators or on direct-indirect radiators. These should be connected up in the usual two pipe standard way.

The radiators are usually set large enough to do the work when eighty per cent of the surface is filled with steam, leaving the remaining twenty per cent to abstract the heat from the water before it flows into the return.

This is accomplished by figuring the radiation required for a low pressure steam system and adding one-quarter or twenty-five per cent to it.

The extreme accuracy of the graduated valve gives perfect control of the room temperature which saves fuel by preventing overheating.

The extra surface in the radiator gives great fuel economy by preventing the waste of the heat in the water. It also


GRADUATED VALVE.
M
70% FILLED WITH STEAM
50% FILLED WITH STEAM.
N
25% FILLED WITH STEAM.
85% FILLED WITH STEAM.
45% FILLED WITH STEAM.
60% FILLED WITH STEAM.
H
K
L
GRADE
GRADE
S
WATER LINE
O
P
Q
R
SERVICE FROM STREET MAIN
J
DRIP

THE ATMOSPHERIC SYSTEM OF STEAM HEATING.
CENTRAL STATION SUPPLY.
"ADSCO" SPECIALTIES.

═ SUPPLY MAIN.
- - - RETURN MAIN (UNCOVERED)
H - AIR LINE TO CHIMNEY OR ATMOSPHERE
J - SERVICE GATE VALVE.
K - PRESSURE REDUCING VALVE.
L - MERCURY GAUGE.
M - GRADUATED VALVE.
N - ORDINARY UNION ELBOW
O - WATER GAUGE AND DRIP FOR MAIN SUPPLY.
P - PIPE RECEIVER.
Q - CONDENSATION METER.
R - METER OUTLET TO SEWER.
S - VENT FOR METER.

NOTE: SHADED PORTION OF RADIATOR SHOWS AIR SPACE DISPLACED BY STEAM AT VARIOUS OPENINGS OF THE GRADUATED VALVE.

EITHER MERCURY OR WATER GAUGE MAY BE INSTALLED AT OWNER'S OPTION.

RADIATION IS OF THE HOT WATER TYPE.

Fig. 7

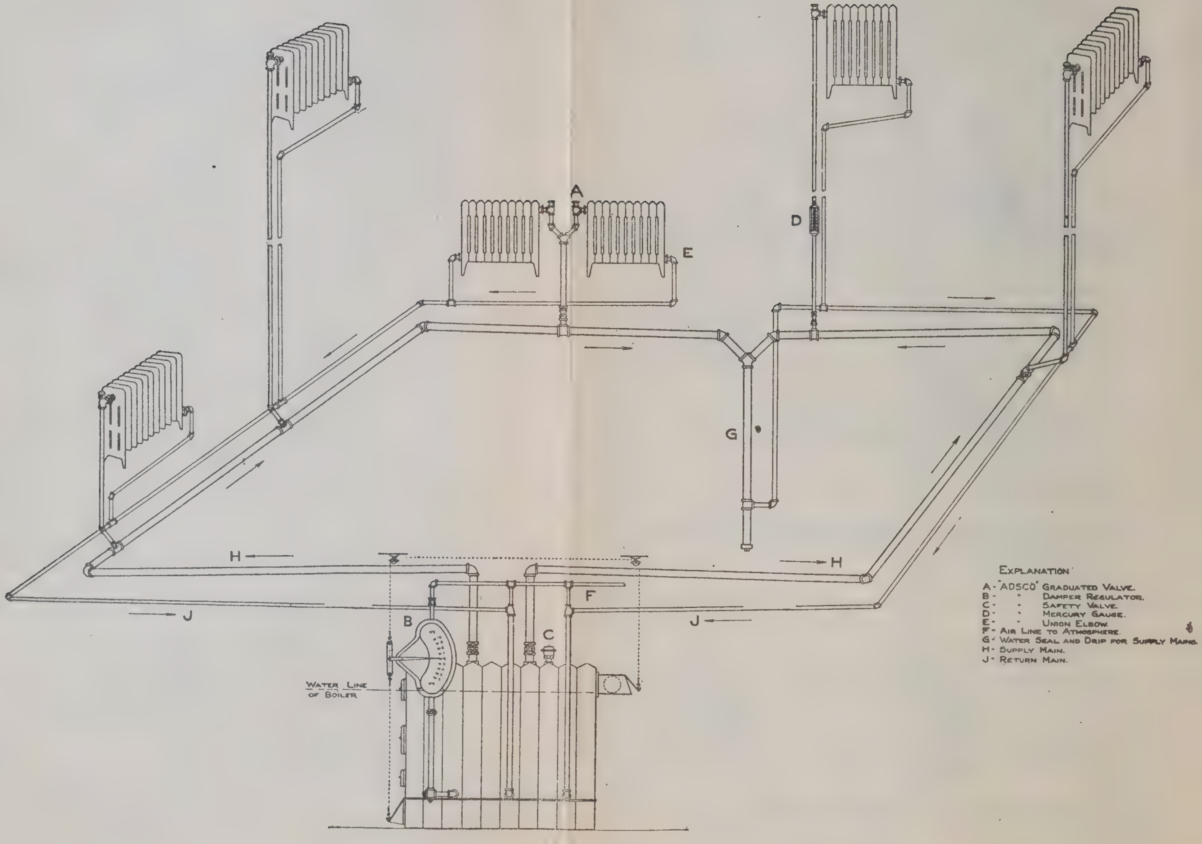

A
D
E
G
H
H
F
J
J
B
C
Water Line of Boiler
Explanation
A - "ADSCO" Graduated Valve.
B - " Damper Regulator.
C - " Safety Valve.
D - " Mercury Gauge.
E - " Union Elbow.
F - Air Line to Atmosphere.
G - Water Seal and Drip for Supply Mains.
H - Supply Main.
J - Return Main.

Fig. 8

provides a safeguard for abnormally cold weather, as the radiator can be entirely filled with steam by raising the steam pressure above the normal operating point.

Fig. 7

Where steam is received from an outside source, the heating company usually extends the service pipe with a gate valve through the building wall ready for extension by others.

The contractor then installs a pressure regulating valve and extends the supply and return piping to the radiators as shown in the illustration.

Water collecting in the supply main is drained through a deep seal into the bottom of a receiver which has an overflow to the meter. A gauge to indicate the pressure is placed on the steam main at a convenient point. Returns are run to the top of the receiver. The water falls into the receiver and overflows into the meter. The air escapes through an open vent pipe from the top of the receiver, which is carried up fifteen feet above the return. The discharge from the meter is connected to sewer, to tank, or to return main in the street as directed by the heating company.

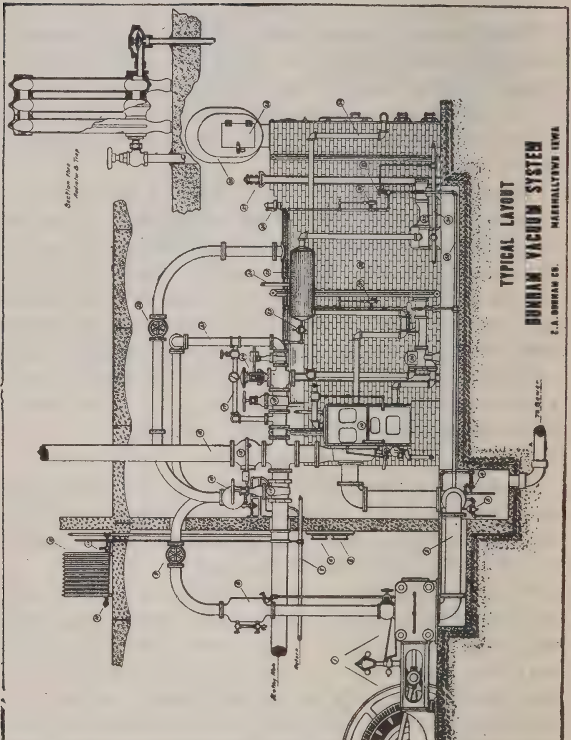
Fig. 8

Where steam is used from a boiler in the building, a system of supply and return piping is installed which is similar in many respects to a standard two pipe steam pressure system, as will be observed from the illustration.

The steam main can be drained through a deep water seal into the return or it can be drained by a separate pipe either wet or dry back to boiler. The returns from the radiators are run to boiler where the water separates from the air and falls into the boiler, the air escaping through the vent pipe which is run up in any convenient flue for at least fifteen feet.

The lowest point of the return mains at the boiler should be at least two feet above the water line. *No check valves are used.*

The damper regulator is adjusted to keep the boiler pressure at the desired point.


TYPICAL LAYOUT
DUNHAM VACUUM SYSTEM
C. A. DUNHAM CO. MARSHALLTOWN IOWA
Section thru Radiator & Trap
To Sewer
Return

Specification Key for Typical Layout of Dunham Vacuum System.

1 Engine and Generator.
2 Exhaust Pipe from Engine.
3 Low Pressure Trap.
4 High Pressure Trap.
5 Vacuum Gauge (Return).
6 Pressure Gauge (Supply).
7 Return Main.
8 Steam Separator.
9 Globe Valve to Engine.
10 Dunham Radiator Trap.
11 Inlet Valve.
12 Radiator.
13 Header on Brackets.
14 Gate Valve to Heating Main.
15 Back Pressure Valve to Roof Exhaust.
16 Roof Exhaust.
17 By-Pass Around Pressure Reducing Valve.
18 Gate Valve Controlling Live Steam into Heating Main.
19 Feed Water Heater.
20 Pressure Reducing Valve.
21 Live Steam Supply.
22 Globe Valve (Boiler to Header).
23 High Pressure Trap.
24 Vent to Atmosphere.
25 Return Tank.
26 Pop Safety Valve.
27 Supports.
28 Breeching.
29 Clean-Out.
30 Feed Water Supply to Boiler.
31 Pressure Reducing Valve.
32 Lubricator.
33 Vacuum Pump.
34 Return.
35 Pump Exhausts.
36 Boiler Feed Pump.
37 Lubricator.
38 Return Tubular Boiler.

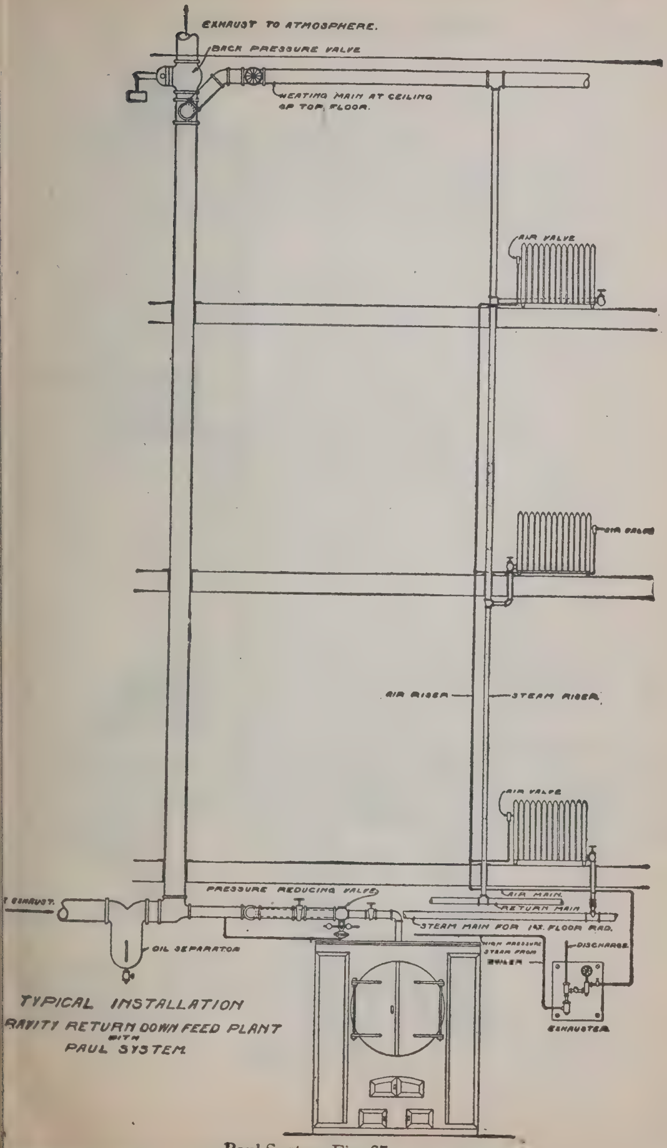
The Paul System.—Figs. 37 and 38.

The Paul System illustrated herewith differs from all other vacuum systems in that it may be applied to a single pipe, gravity plant as well as to a two-pipe plant; and further, because the vacuum is obtained direct in each individual radiator by connecting the air pipe to an automatic air-valve of special design.

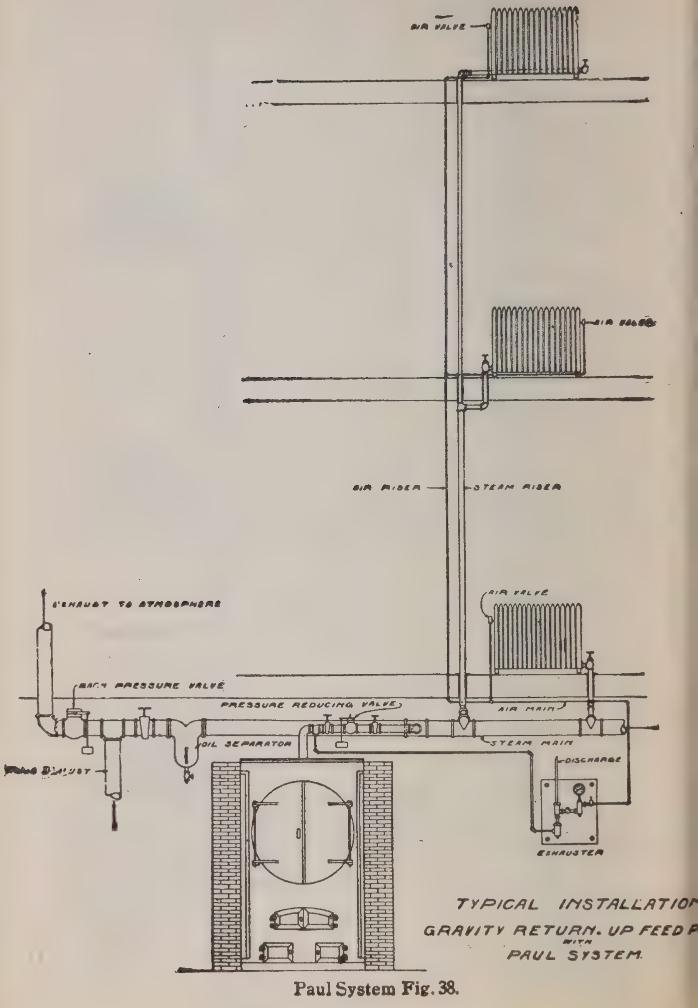
Taking advantage of the fact that water will return to the lowest point, the Paul System is designed for the independent removal of air only, this being accomplished before steam is admitted. The air pipe being connected to the automatic air valve at the end of the radiator or coil farthest removed from the admission valve and supply pipe, and a vacuum being thereby produced in all sections, complete and immediate circulation of steam must result. It is apparent that circulation will be maintained in all radiators by reason of decrease in volume due to condensation of the steam.

The standard apparatus used with the Paul System is remarkable for its simplicity of design and operation. In connection with heating plants using exhaust steam, a special exhausting apparatus operated with live steam is used for producing vacuum. Unlike ordinary pumps it has no moving parts and no mechanism requiring attention or repairs. In low pressure plants where live steam is not available, an automatic water exhauster of simple design, or a small electric air pump, is used to accomplish the same results.

The illustrations show the system as applied either to up-feed or down-feed plants, as may be indicated or required by existing conditions.


EXHAUST TO ATMOSPHERE.
BACK PRESSURE VALVE
HEATING MAIN AT CEILING OF TOP FLOOR.
AIR VALVE
AIR VALVE
AIR RISER
STEAM RISER
AIR VALVE
PRESSURE REDUCING VALVE
EXHAUST.
AIR MAIN.
RETURN MAIN
STEAM MAIN FOR 1ST. FLOOR RAD.
OIL SEPARATOR
HIGH PRESSURE STEAM FROM BOILER
DISCHARGE.
EXHAUSTER
TYPICAL INSTALLATION
RAVITY RETURN DOWN FEED PLANT
WITH
PAUL SYSTEM

Paul System Fig. 37.


AIR VALVE
AIR VALVE
AIR RISER
STEAM RISER
AIR VALVE
EXHAUST TO ATMOSPHERE
BACK PRESSURE VALVE
PRESSURE REDUCING VALVE
AIR MAIN
OIL SEPARATOR
STEAM MAIN
EXHAUST
DISCHARGE
EXHAUSTER
TYPICAL INSTALLATIO
GRAVITY RETURN. UP FEED P
WITH
PAUL SYSTEM.

Paul System Fig. 38.

Capacity of Vacuum Pumps.

The capacity of a Vacuum Pump to handle a given amount of heating surface depends largely upon the character of the buildings.

Thus, if the return mains are long, and the job spread out over several scattered buildings, a larger pump is required than if the same number of square feet of radiation were all in one building several stories high.

Again, the number of radiators, or units of heating surface, makes some difference, as a larger pump should be used where there are a large number of small units than would be necessary for the same amount of heating surface if divided into fewer, large units.

We list herewith the standard sizes of Vacuum Pumps with their average capacities in square feet of heating surface. These capacities are for use where each coil and radiator is equipped with an Automatic Vacuum Trap as in the Standard Vacuum Systems described in this book, as these Traps and Valves are necessary to prevent the Vacuum Pump pulling steam out of the heating system.

The standard sizes given can be used where there is ordinary steam pressure, say 40 to 100 lbs. If the steam pressure is lower it is necessary to use a pump with a large steam cylinder, or, if high pressure is carried at all times, a smaller steam cylinder may be used. For instance, if a 5″x7″x10″ pump would ordinarily be used, if steam pressure is to be low—10 to 20 lbs.—it would be better to use a 6″x7″x10″, or a 6″x6″x12″ would give the same capacitv and run on 10 lbs. steam pressure.

Capacities are given in square feet of direct heating surface, or lineal feet of 1″ pipe in Blast Coils.

Dia. Steam Cylinder.		Dia. Vaccuum Cylinder			Capacity in Sq. Ft.
4″	x	4″	x	5″	2000
4″	x	6″	x	7″	3000
4½″	x	6″	x	8″	5000
5½″	x	8″	x	7″	6000
5″	x	7″	x	10″	7500
5″	x	8″	x	10″	10000
6″	x	9″	x	10″	15000
6″	x	8″	x	12″	20000
8″	x	10″	x	12″	35000
8″	x	12″	x	12″	50000

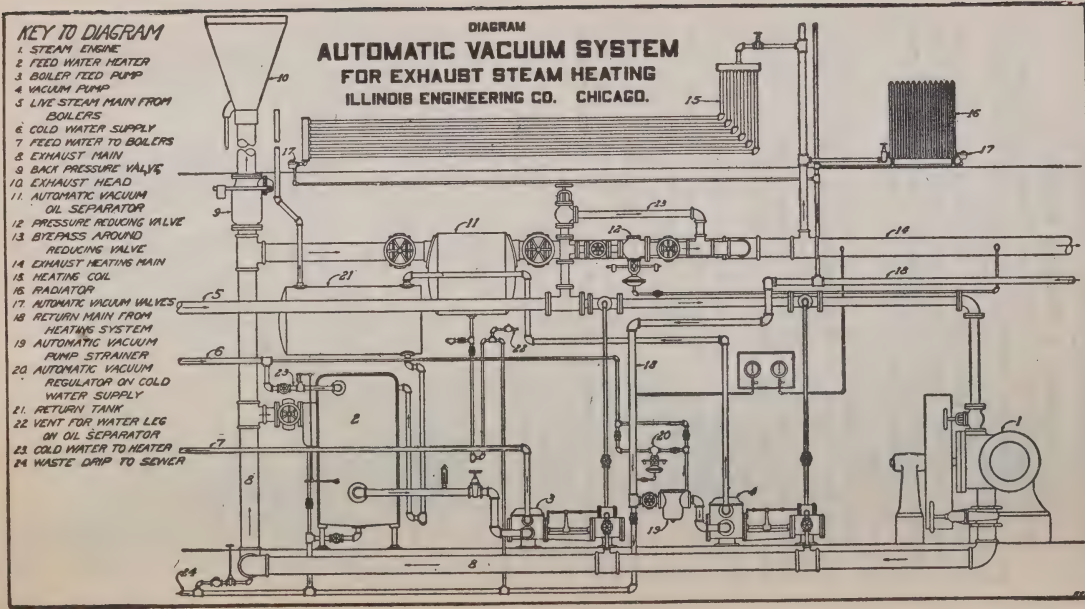

KEY TO DIAGRAM
1. STEAM ENGINE
2. FEED WATER HEATER
3. BOILER FEED PUMP
4. VACUUM PUMP
5. LIVE STEAM MAIN FROM BOILERS
6. COLD WATER SUPPLY
7. FEED WATER TO BOILERS
8. EXHAUST MAIN
9. BACK PRESSURE VALVE
10. EXHAUST HEAD
11. AUTOMATIC VACUUM OIL SEPARATOR
12. PRESSURE REDUCING VALVE
13. BYEPASS AROUND REDUCING VALVE
14. EXHAUST HEATING MAIN
15. HEATING COIL
16. RADIATOR
17. AUTOMATIC VACUUM VALVES
18. RETURN MAIN FROM HEATING SYSTEM
19. AUTOMATIC VACUUM PUMP STRAINER
20. AUTOMATIC VACUUM REGULATOR ON COLD WATER SUPPLY
21. RETURN TANK
22. VENT FOR WATER LEG ON OIL SEPARATOR
23. COLD WATER TO HEATER
24. WASTE DRIP TO SEWER
DIAGRAM
AUTOMATIC VACUUM SYSTEM
FOR EXHAUST STEAM HEATING
ILLINOIS ENGINEERING CO. CHICAGO.
10
15
16
17
17
9
23
11
12
14
21
18
5
28
6
18
23
2
20
7
8
3
4
19
1
8
24

Fig. 36.

Vacuum System—Fig. 36.

The great economy and general advantages resulting from the use of a Vacuum System for heating with exhaust steam are now generally recognized, and make this type of heating system of the greatest importance to the steam-fitter.

As very little if any description of Vacuum Systems appears in books on heating, we give a layout of piping for a complete Vacuum System for heating with exhaust steam. The system illustrated is the one which shows the latest improvements and developments in the art of Vacuum Heating.

The diagram shows the different apparatus usual in any power plant, and the special Vacuum appliances in their proper location. The accompanying key to the diagram gives the names of the various parts of the system, each number on the diagram having a corresponding number on the key.

The piping necessary for best results is shown and the arrows on the piping show the direction of flow of steam, water, etc.

The arrangement of exhaust main (8), from engines (1), pumps (3 and 4), etc., up to exhaust head (10), with connection to Feed Water Heater (2), and heating main (14) taken off under back pressure valve (9), is common to all exhaust heating systems.

The oil separator, or grease extractor (11), shown in heating main, is a new improved type having an area between baffles of four times the area of the pipe, this slows the velocity of the steam so that practically all the oil is deposited on the baffles.

The drip from separator to sewer is shown as a water loop to prevent steam from blowing to sewer. Instead of the water seal a grease trap may be placed on the drip.

(12) is a connection to the live steam through a reducing valve, the controlling pressure being connected to the heating main (14).

(13) is a byepass around reducing valve for emergency use.

From heating main (14) risers are taken off to supply the radiators or coils (15 or 16).

On the return ends of all units of radiation (15 and 16), are placed automatic vacuum valves of proper capacity for the size of each unit. These valves permit the vacuum in the returns to pull all air and water of condensation from the radiators and assist the flow of steam into the radiators without the loss of steam into the return lines. The valves are of the float type which immediately open to full capacity as soon as the body of valve is filled with water. They are automatic, require no adjustment, and are provided with a strainer to keep scale out of the valve, they also have a byepass with lock shield and key.

All the returns from the automatic vacuum valves unite into a return main (18) running to vacuum pump (4). Before the vacuum pump an automatic pump strainer (19) is placed.

This strainer prevents scale, filings, etc., from entering pump cylinder, and it also has a connection for cold water which is sprayed over the screen through a spray head. On this cold water pipe is placed the automatic vacuum governor (20), the controlling pressure is connected to the vacuum return (18) and the operation is as follows:

When the vacuum in (18) is low, say 5 inches, the governor opens and admits cold water to assist in holding vacuum, when the vacuum gets up to say 12 inches, the governor entirely closes off the cold water. The weights on governor are adjusted so that valve may be set to open or close on any range of vacuum. In this manner any desired vacuum can be maintained, and the usual constant flow of cold water which floods the heater to the sewer is prevented.

At the bottom of (18) is shown a byepass connection to sewer, so that plant can be operated as a gravity system temporarily if vacuum pump or heater are being repaired.

The discharge pipe from vacuum pump to heater is shown running into a return tank (21), with an air vent to roof. With a closed heater the feed pump pulls from the return tank and pumps to boilers through heater. With an open heater the tank may be small, as it simply serves the purpose of liberating air from the feed water, the water loop shown between air vent tank and heater prevents steam from escaping from heater.

With such a vacuum system exhaust steam may be circulated to heat groups of buildings several thousand feet from the power house, and without back pressure on the engines. Back pressure which is necessary for circulation in a gravity system causes loss; with 80 lbs. boiler pressure, an engine having 5 lbs. back pressure will use about 15% more steam than it will without the back pressure.

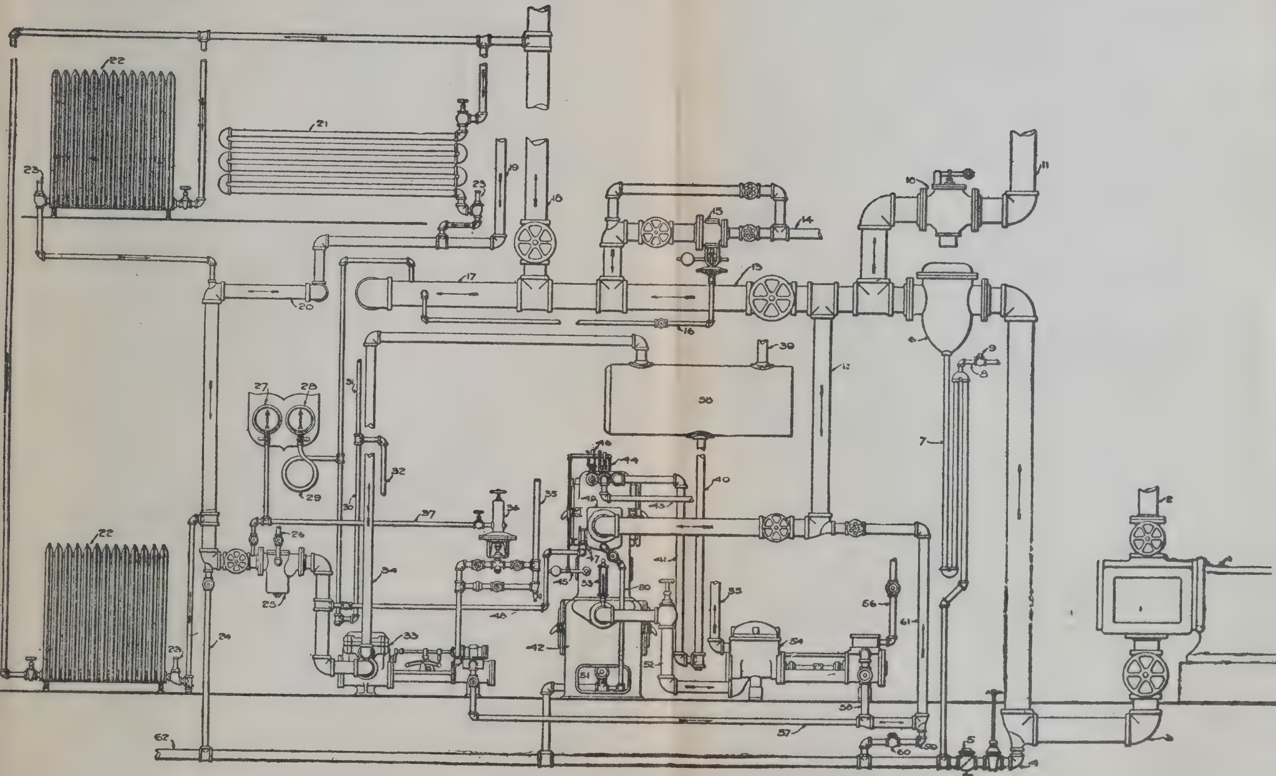
In addition to this fuel saving, a Vacuum System which removes air and water of condensation from the radiation gives perfect circulation without water hammer, air binding, or water logging of the heating system.

The many advantages secured by the use of an improved Vacuum System are so important that very few heating plants of any size are now installed without a Vacuum System.

Key to Diagram Fig. 35.

Illustrating the Webster System of Steam Circulation for Heating Purposes.

1. Steam engine.
2. Live steam supply to engine.
3. Exhaust steam from engine.
4. Drip.
5. Check-valve.
6. Grease extractor.
7. Water leg.
8. Anti-syphonage vent.
9. Check-valve.
10. Back-pressure valve.
11. Waste exhaust steam to atmosphere.
12. Exhaust steam supply to feed-water heater.
13. Exhaust steam supply to house heating main.
14. Live steam supply to house heating main.
15. Pressure-reducing valve.
16. Connection from house heating main communicating pressure to diaphragm of pressure-reducing valve.
17. House heating main.
18. Heating riser.
19. Return.
20. Return main.
21. Heating coil.
22. Radiators.
23. Thermostatic return valves.
24. Drip.
25. Dirt strainer.
26. Cold water supply.
27. Return vaccum gauge.
28. Supply pressure gauge.
29. Water seal.
30. Water leg.
31. Vent.
32. Drip.
33. Return pumps.
34. Discharge to return pump
35. Live steam supply to return pump.
36. Differential regulator or vacuum governor.
37. Connection from return to differential regulator.
38. Return tank.
39. Vent.
40. 41. Return and seal to feed-water heater.
42. Feed-water heater.
43. Cold water supply to feed-water heater.
44. Automatic valve.
45. Float-operated lever.
46. Safety valve.
47. Thermostatic relief valve.
48. Relief connection to return pipe.
49. Grease extractor.
50. Greasy waste to sewer.
51. Overflow and drain from feed-water heater.
52. Feed-water to boiler feed pump.
53. Feed-water thermometer.
54. Boiler feed pump.
55. Feed-water to boiler.
56. Live steam supply to boiler feed pump.
57. Exhaust steam from return pump.
58. Exhaust steam from boiler feed pump.
59. Drip.
60. Check-valve.
61. Exhaust steam pumps to feed-water heater.
62. Waste drips to sewer.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57
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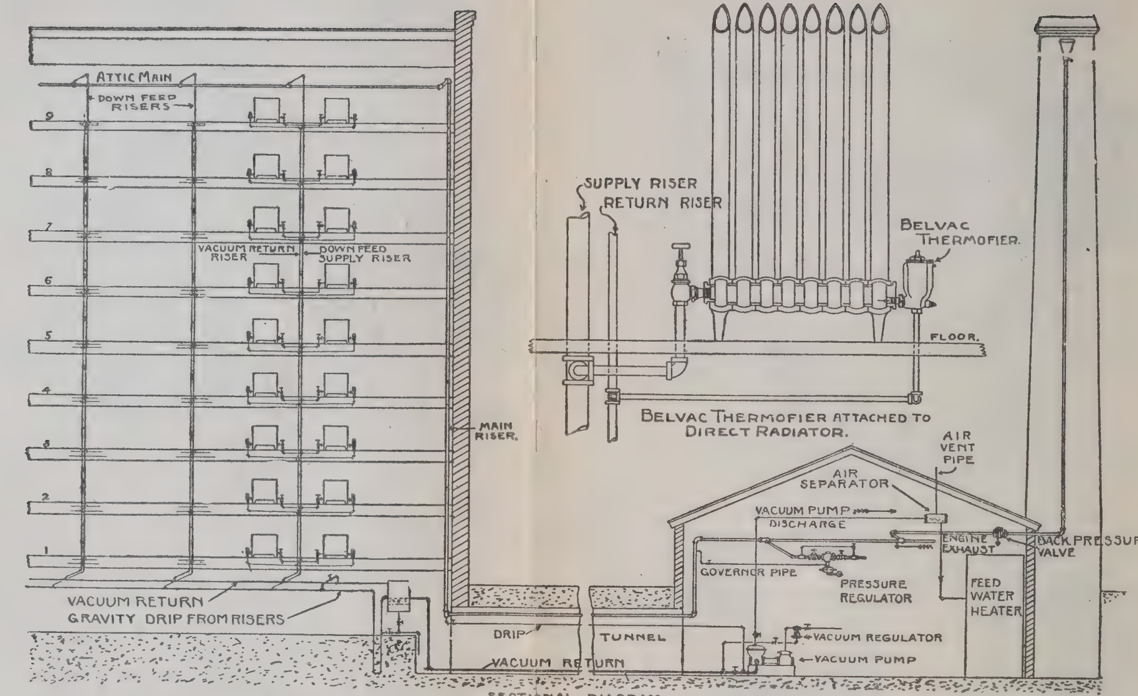
60
5

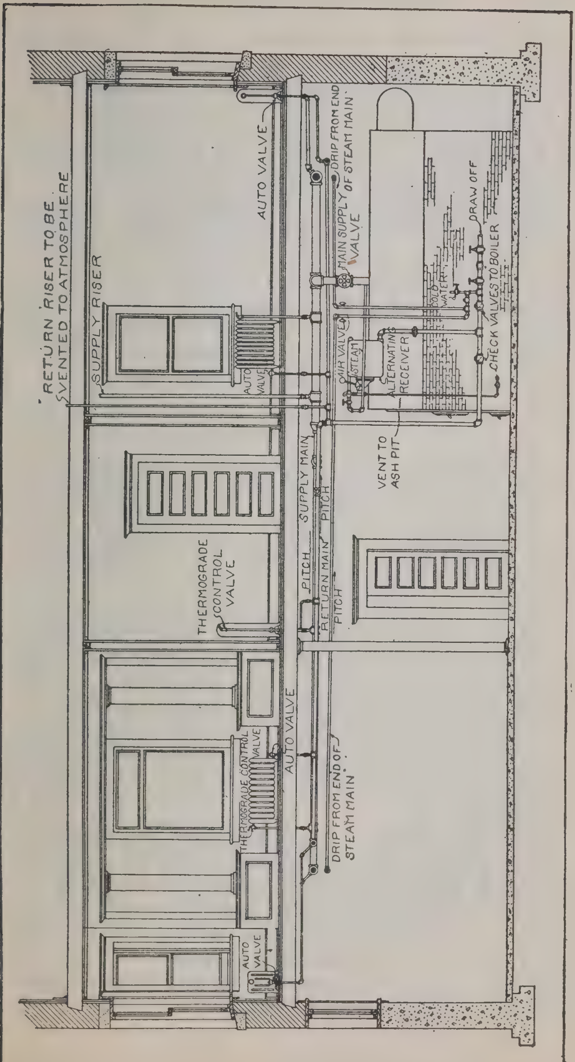
The Webster System.—Fig. 35


ATTIC MAIN
DOWN FEED RISERS
9
8
7
6
5
4
3
2
1
VACUUM RETURN RISER
DOWN FEED SUPPLY RISER
MAIN RISER.
VACUUM RETURN
GRAVITY DRIP FROM RISERS
DRIP
VACUUM RETURN
TUNNEL
SUPPLY RISER
RETURN RISER
BELVAC THERMOFIER.
FLOOR.
BELVAC THERMOFIER ATTACHED TO DIRECT RADIATOR.
AIR VENT PIPE
AIR SEPARATOR
VACUUM PUMP DISCHARGE
ENGINE EXHAUST
BACK PRESSUR VALVE
GOVERNOR PIPE
PRESSURE REGULATOR
FEED WATER HEATER
VACUUM REGULATOR
VACUUM PUMP

SECTIONAL DIAGRAM
GIVING GENERAL VIEW OF INSTALLATION IN THE "LESSING ANNEX."
EVANSTON AVE. & SURF ST., CHICAGO.

VAN AUKEN SYSTEM OF VACUUM HEATING,
WITH
BELVAC THERMOFIERS.

Fig. 34


RETURN RISER TO BE VENTED TO ATMOSPHERE
SUPPLY RISER
AUTO VALVE
DRIP FROM END OF STEAM MAIN
MAIN SUPPLY VALVE
AUTO VALVE
AIR VALVE
STEAM
ALTERNATING RECEIVER
COLD WATER
DRAW OFF
CHECK VALVES TO BOILER
VENT TO ASH PIT
SUPPLY MAIN
PITCH
PITCH
RETURN MAIN
PITCH
PITCH
THERMOGRADE CONTROL VALVE
AUTO VALVE
THERMOGRADE CONTROL VALVE
DRIP FROM END OF STEAM MAIN
AUTO VALVE

Thermograde System of Heat Modulation

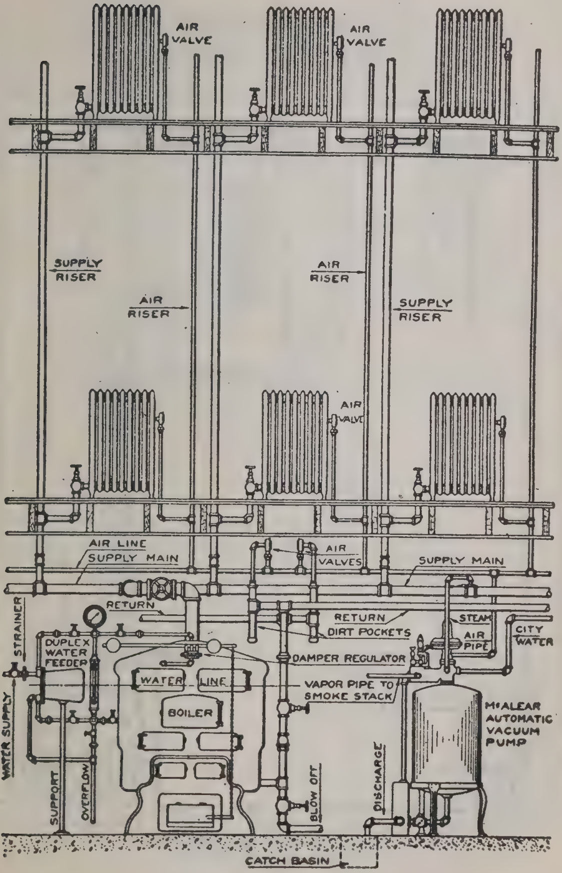
The following cut illustrates the Thermograde System of steam heating, as manufactured by the Consolidated Engineering Company. Steam is distributed to different units of radiation through a system of mains in the ordinary manner and water of condensation is returned to the boiler through an independent system of return mains.

Each unit of radiation is equipped with a Thermograde valve at the supply end and an auto valve at the return. The Thermograde valve is connected at the top of the radiator and is provided with a graduated dial, indicating the portion of the radiator to be heated. The valve is so constructed that it may be adjusted to give the proper graduation to different size radiators supplied with the same size valve.

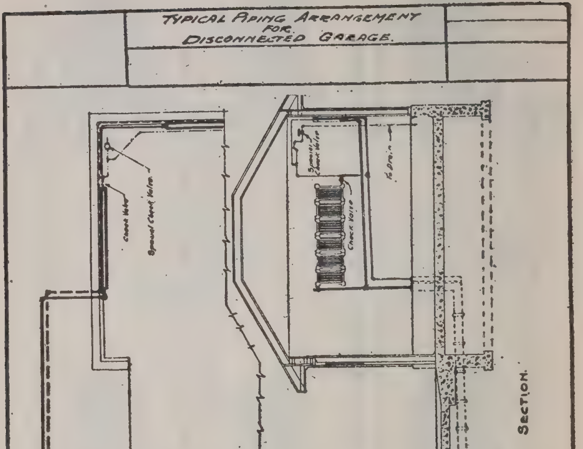
The auto valve is a trap of the thermostatic type which permits of the free passage of air and water of condensation, but closes against the passage of steam. When in operation the valve automatically assumes a position off the seat, directly proportional to the quantity of steam condensed in the radiator. The return system is vented to the atmosphere through the return risers.

When operating under normal conditions with about one pound pressure on the boiler the head of water from the water line of the boiler to the return main is sufficient to force the water into the boiler, but when the pressure is increased, either intentionally or through inattention, the water of condensation flows into the alternating receiver, the air being discharged through a vent pipe provided for the purpose.

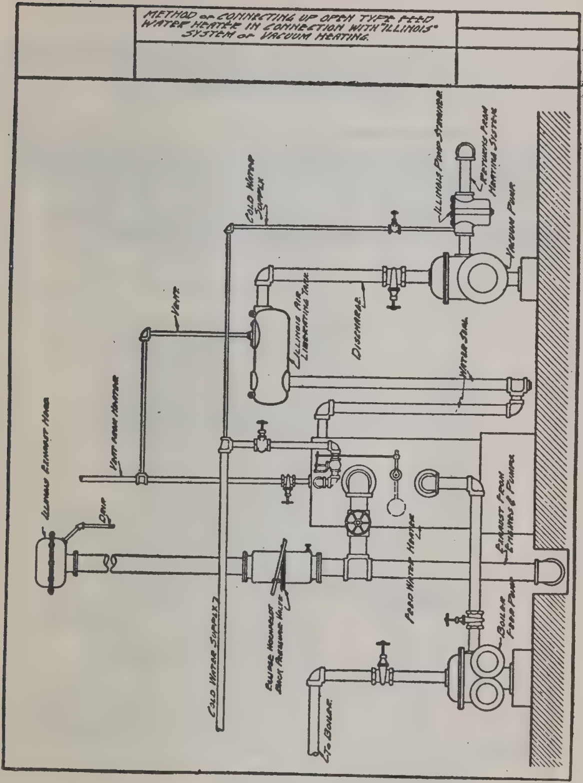
When the receiver fills with water the float controlled valve is reversed, closing the air vent and admitting steam from the boiler. This closes the check valve on the heating system, equalizing the pressure between the receiver and the boiler and water flows into the boiler by gravity. When the receiver empties, the position of the valve is again changed and the action repeated.


AIR VALVE
AIR VALVE
SUPPLY RISER
AIR RISER
AIR RISER
SUPPLY RISER
AIR VALVE
AIR LINE
SUPPLY MAIN
AIR VALVES
SUPPLY MAIN
STRAINER
RETURN
RETURN
DIRT POCKETS
STEAM
AIR PIPE
CITY WATER
DUPLEX WATER FEEDER
DAMPER REGULATOR
WATER LINE
VAPOR PIPE TO SMOKE STACK
BOILER
McALEAR AUTOMATIC VACUUM PUMP
WATER SUPPLY
SUPPORT
OVERFLOW
BLOW OFF
DISCHARGE
CATCH BASIN

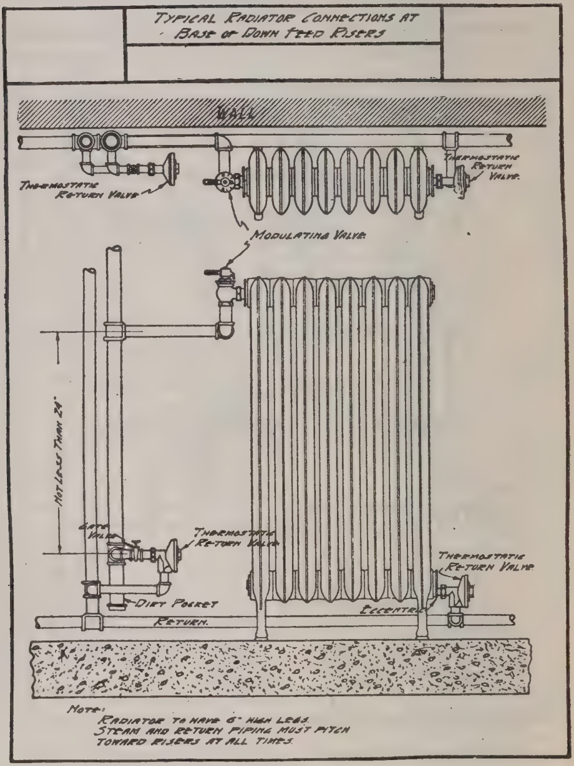
McAlear Vapor System.


TYPICAL PIPING ARRANGEMENT FOR DISCONNECTED GARAGE.
PLAN.
SECTION.
Check Valve
Spencer Check Valve
Spencer Check Valve
Check Valve
To Drain
Thermo Drip Valve
Thermo Drip Valve
Spencer Check Valve
Newport Boiler
Spencer Check Valve

Simple method of heating garage by use of Illinois Vapor System.

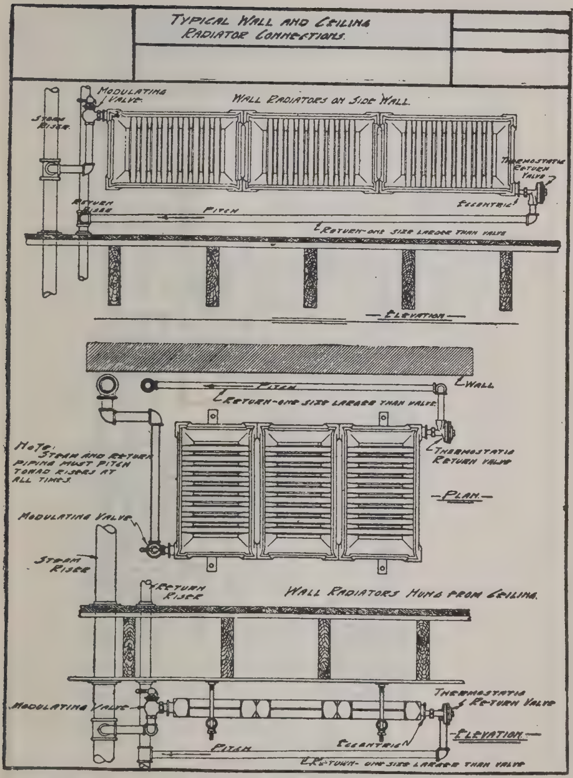

METHOD OF CONNECTING UP OPEN TYPE FEED WATER HEATER IN CONNECTION WITH "ILLINOIS" SYSTEM OF VACUUM HEATING.
COLD WATER SUPPLY
ILLINOIS PUMP STRAINER
RETURNS FROM HEATING SYSTEM
VACUUM PUMP
VENT
ILLINOIS AIR LIBERATING TANK
DISCHARGE
WATER SEAL
VENT FROM HEATER
ILLINOIS EXHAUST HEAD
DRIP
COLD WATER SUPPLY
ILLINOIS HOCHHOLDT BACK PRESSURE VALVE
FEED WATER HEATER
EXHAUST FROM ENGINES & PUMPS
BOILER FEED PUMP
TO BOILER

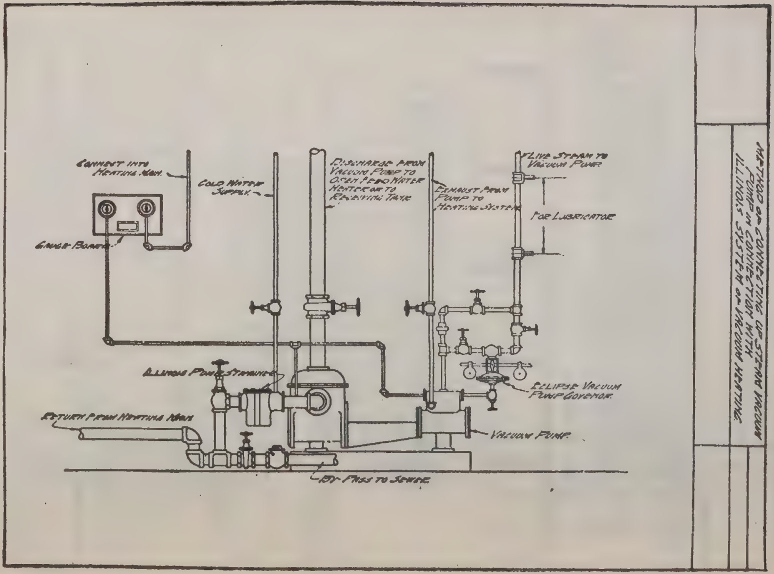
The Illinois Vacuum and Vapor Systems are considered among the very best, as they contain a better method of returning the air and condensation. See the following illustrations.


TYPICAL RADIATOR CONNECTIONS AT
BASE OF DOWN FEED RISERS
WALL
THERMOSTATIC RETURN VALVE
MODULATING VALVE
THERMOSTATIC RETURN VALVE.
NOT LESS THAN 24"
GATE VALVE
THERMOSTATIC RETURN VALVE
THERMOSTATIC RETURN VALVE
DIRT POCKET
ECCENTRIC
RETURN.

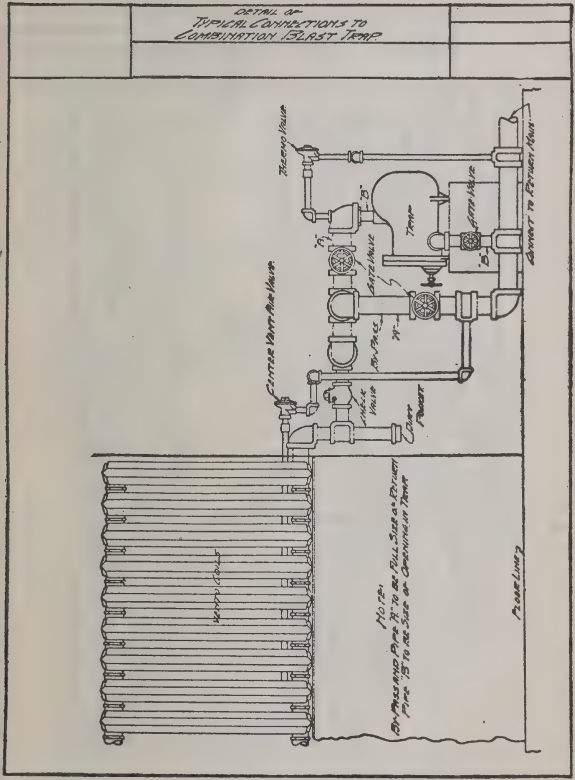
NOTE:
RADIATOR TO HAVE 6" HIGH LEGS.
STEAM AND RETURN PIPING MUST PITCH
TOWARD RISERS AT ALL TIMES.

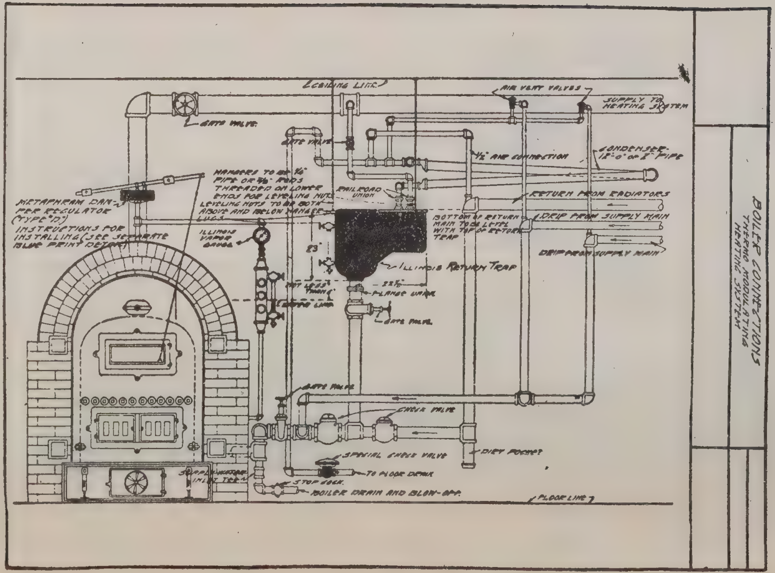
Illinois Vapor Valves.

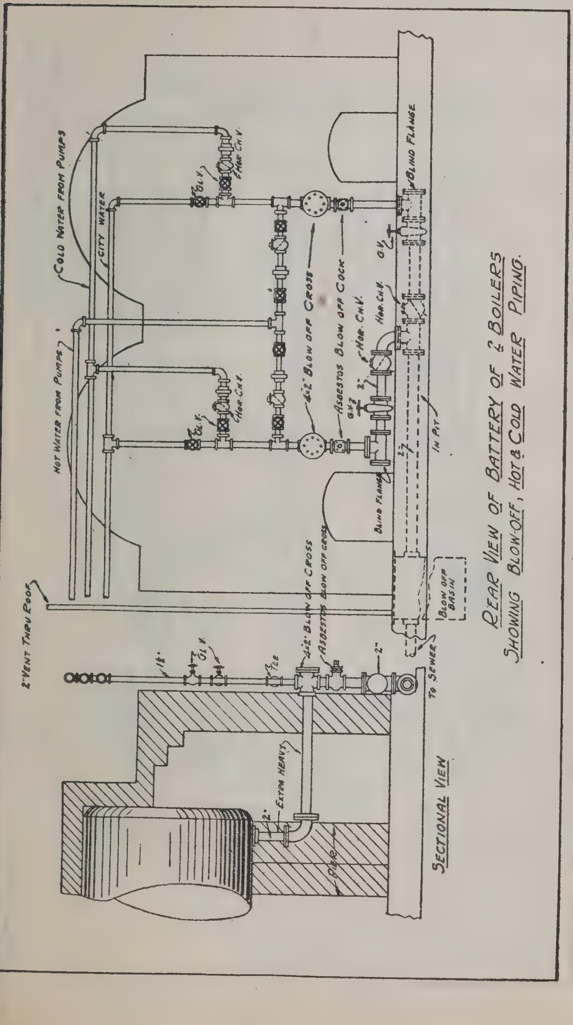

TYPICAL WALL AND CEILING RADIATOR CONNECTIONS.
MODULATING VALVE.
WALL RADIATORS ON SIDE WALL.
STEAM RISER.
THERMOSTATIC RETURN VALVE
RETURN RISER
PITCH
ECCENTRIC
RETURN-ONE SIZE LARGER THAN VALVE
—ELEVATION—
PITCH
WALL
RETURN-ONE SIZE LARGER THAN VALVE.
THERMOSTATIC RETURN VALVE
NOTE: STEAM AND RETURN PIPING MUST PITCH TOWAD RISERS AT ALL TIMES.
—PLAN.—
MODULATING VALVE
STEAM RISER
RETURN RISER
WALL RADIATORS HUNG FROM CEILING.
MODULATING VALVE
THERMOSTATIC RETURN VALVE
—ELEVATION.—
ECCENTRIC
PITCH
RETURN- ONE SIZE LARGER THAN VALVE


CONNECT INTO HEATING MAIN.
COLD WATER SUPPLY.
DISCHARGE FROM VACUUM PUMP TO OPEN FEED WATER HEATER OR TO RECEIVING TANK
EXHAUST FROM PUMP TO HEATING SYSTEM
LIVE STEAM TO VACUUM PUMP
FOR LUBRICATOR
GAUGE BOARD
ILLINOIS PUMP STRAINER
ECLIPSE VACUUM PUMP GOVERNOR
RETURN FROM HEATING MAIN
VACUUM PUMP.
BY-PASS TO SEWER

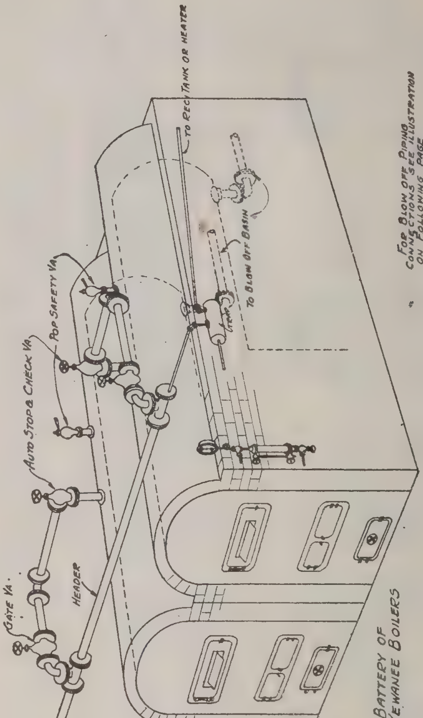
METHOD OF CONNECTING UP STEAM VACUUM PUMP IN CONNECTION WITH ILLINOIS SYSTEM OF VACUUM HEATING.


DETAIL OF
TYPICAL CONNECTIONS TO
COMBINATION BLAST TRAP.
THERMO VALVE.
CENTER VENT AIR VALVE.
"A"
"B"
GATE VALVE
TRAP
GATE VALVE
"B"
BY-PASS
"A"
CHECK VALVE
DIRT POCKET
CONNECT TO RETURN MAIN
VENTO COILS
NOTE:
BY-PASS AND PIPE "A" TO BE FULL SIZE OF RETURN
PIPE "B" TO BE SIZE OF OPENING IN TRAP
FLOOR LINE


BOILER CONNECTIONS
THERMO MODULATING
HEATING SYSTEM
CEILING LINE
AIR VENT VALVES
SUPPLY TO HEATING SYSTEM
GATE VALVE
GATE VALVE
½" AIR CONNECTION
CONDENSER 12'-0" OF 2" PIPE
HANGERS TO BE ½" PIPE OR ⅜" RODS THREADED ON LOWER ENDS FOR LEVELING NUTS
LEVELING NUTS TO BE BOTH ABOVE AND BELOW HANGER LUGS
RAILROAD UNION
RETURN FROM RADIATORS
DIAPHRAM DAMPER REGULATOR (TYPE "D")
INSTRUCTIONS FOR INSTALLING (SEE SEPARATE BLUE PRINT DETAIL)
ILLINOIS VAPOR GAUGE
BOTTOM OF RETURN MAIN TO BE LEVEL WITH TOP OF RETURN TRAP
DRIP FROM SUPPLY MAIN
DRIP FROM SUPPLY MAIN
23"
ILLINOIS RETURN TRAP
NOT LESS THAN 6"
22½"
FLANGE UNION
WATER LINE
GATE VALVE
GATE VALVE
CHECK VALVE
SPECIAL CHECK VALVE
DIRT POCKET
TO FLOOR DRAIN
SUPPLY WATER INLET TEE
STOP COCK
BOILER DRAIN AND BLOW-OFF
FLOOR LINE


COLD WATER FROM PUMPS
CITY WATER
HOT WATER FROM PUMPS
GL.V.
HOR. CH.V.
GL.V.
HOR. CH.V.
4½" BLOW OFF CROSS
ASBESTOS BLOW OFF COCK
HOR. CH.V.
HOR. CH.V.
G.V.
G.V.
2"
2½"
IN PIT
BLIND FLANGE
BLIND FLANGE
BLOW OFF BASIN
TO SEWER
2" VENT THRU ROOF
4½" BLOW OFF CROSS
ASBESTOS BLOW OFF CROSS
1½"
GL.V.
2" TEE
2"
EXTRA HEAVY
2"
PIER
SECTIONAL VIEW

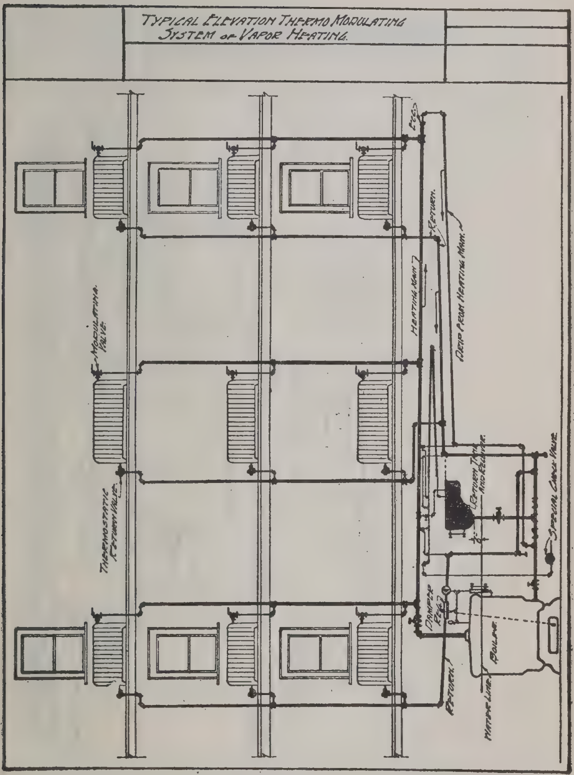
REAR VIEW OF BATTERY OF 2 BOILERS
SHOWING BLOW-OFF, HOT & COLD WATER PIPING.

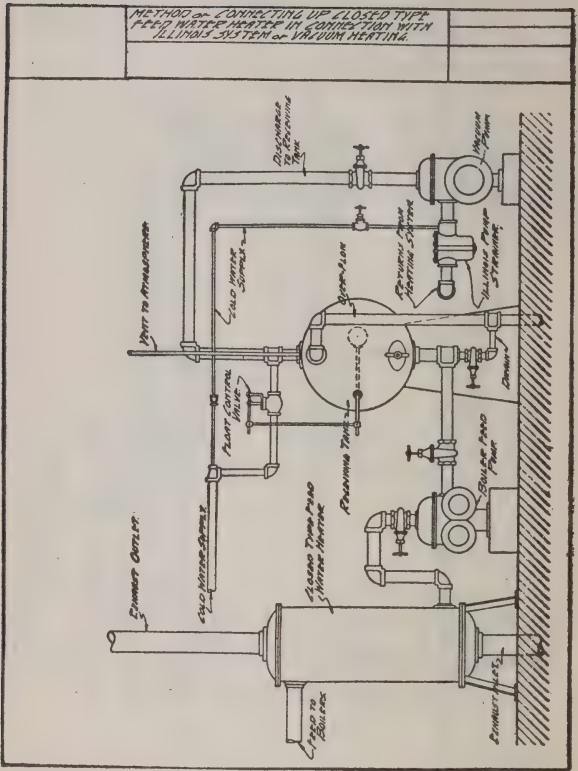

GATE VA.
HEADER
AUTO STOP & CHECK VA.
POP SAFETY VA.
TO REC. TANK OR HEATER
TRAP
TO BLOW OFF BASIN

BATTERY OF TWO KEWANEE BOILERS

FOR BLOW OFF PIPING CONNECTIONS SEE ILLUSTRATION ON FOLLOWING PAGE

THIS ILLUSTRATION SHOWS CORRECT WAY OF MAKING CONNECTIONS TO HEADER WITH SWING JOINTS TO TAKE UP EXPANSION.


TYPICAL ELEVATION THERMO MODULATING SYSTEM OF VAPOR HEATING.
MODULATING VALVE.
THERMOSTATIC RETURN VALVE.
HEATING MAIN.
RETURN.
DRIP FROM HEATING MAIN.
RETURN TANK AND RECEIVER.
SPECIAL CHECK VALVE.
DAMPER REG.
BOILER.
WATER LINE.
RETURN.



METHOD OF CONNECTING UP CLOSED TYPE FEED WATER HEATER IN CONNECTION WITH ILLINOIS SYSTEM OF VACUUM HEATING.

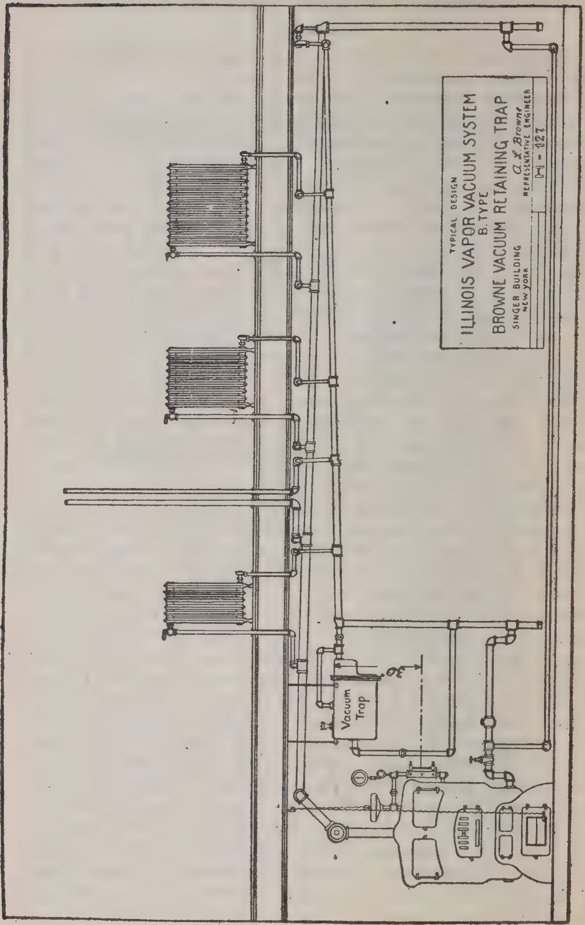
DISCHARGE TO RECEIVING TANK
VACUUM PUMP
VENT TO ATMOSPHERE
COLD WATER SUPPLY
RETURNS FROM HEATING SYSTEM
ILLINOIS PUMP STRAINER
OVERFLOW
DRAIN
FLOAT CONTROL VALVE
RECEIVING TANK
BOILER FEED PUMP
EXHAUST OUTLET
COLD WATER SUPPLY
CLOSED TYPE FEED WATER HEATER
FEED TO BOILERS
EXHAUST INLET

Description of Brown Vacuum Retaining Trap

Referring to the cross sectional views illustrating the three functions of this Trap.

Neutral Position illustrates the trap in an inoperating condition, or acting as an air expeller. Air from the heating system at a very slight pressure enters the trap through pipe connection "A" and thence through the smaller pipe "B" with a connection at the top of Chamber "D," and extending down below the water line ½ inch. The portion of the pipe within the Chamber "D" is brass. It will be observed that the air will blow through the ½ inch seal of water, which represents less than 1/50 pound back pressure, which is practically null. And, in so doing is washed of solid impurities, such as pipe scale, particles of core sand, etc., and this passes out through the valve members "1" and "2" which during this operation, are wide open. Therefore, there is no additional restriction to the free and easy passage of air from the heating system, and it is obvious that the valve members are, in this manner, kept perfectly clean.

Vacuum Retaining Position illustrates the trap operating under vacuum conditions when the boiler is banked and the radiators condense steam faster than the boiler is evaporating it, and vacuum occurs. This vacuum exerts itself on a surface of the water in Chamber "E," whose only connection with Chamber "D" is through port "H," connecting Chamber "E" with the float bowl in Chamber "D." This causes the water to rise in Chamber " E," which is relatively large in proportion to the float bowl. Therefore, a slight rise of water in Chamber "E" causes a decided drop of the float "8." Simultaneously, with this operation, the air expelling pipe "B" then acts as a balance head against Chamber "E," and water from Chamber "D" will enter this pipe and rise in it, due to the fact of the vacuum of the heating system, which exerts its influence exactly the same through pipe "A" into Chamber "E" and Chamber "D" through pipe "B." Therefore, we have a condition of an exactly similar head of water as to height in balance head pipe "B" and in Chamber "E," although


TYPICAL DESIGN
ILLINOIS VAPOR VACUUM SYSTEM
B. TYPE
BROWNE VACUUM RETAINING TRAP
SINGER BUILDING
NEW YORK
A. L. Browne
REPRESENTATIVE ENGINEER
H-127
Vacuum Trap

these two heads of water are at two different levels.

When the water is completely withdrawn from the float bowl through port "H" into Chamber "E," due to the increasing vacuum which occurs at about ½ inch of vacuum, it leaves the float suspended in the air, and due to the leverage as indicated by float arm "6," and valve connection "7," 8½-pound closing pressure is applied to vacuum valve "1." This positive action and pressure at a slight vacuum at this point prevents any air from re-entering the heating system through this device after it has been expelled. To accomplish this result so far, two points are illustrated that the valve members are automatically kept clean and a positive pressure of considerable force is applied to the valve in closing at a very slight vacuum.

Return Trap Position illustrating the trap operating to return the water of condensation to the boiler when a pressure is carried at the boiler. It will be understood that in a thermostatic radiator trap system that there is no pressure in the dry return therefore, it becomes necessary when pressure is carried upon the boiler to devise some means to return this water to the boiler against boiler pressure. Pressure in the boiler would cause water to gradually rise in the trap through overflow pipe connection "C," causing the float to rise and closing the return valve "2." However, rise of water in the trap compresses the air within it and the dry return line and thereby builds up a pressure in the return line approximately equivalent to the steam pressure in the supply mains. When this point is reached, additional condensation is returned automatically by gravity to the boiler due to this equalization.

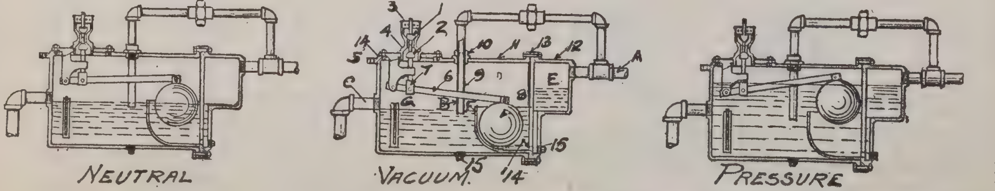
It will be noted that the mechanical parts of this trap are very simple, consisting of a compound bronze valve member and an aluminum float arm, and a seamless copper float, moving 2½ inches up and 2½ inches down from the neutral position.

The weight of this trap is roughly 130 pounds and approximate measures are 24 inches long, 9 inches wide, and 11 inches high. The capacity of the 1-A trap is 5000 radiation, and the 1-B is 10000.

Cross Section

showing functions of

BROWNE VACUUM RETAINING TRAP

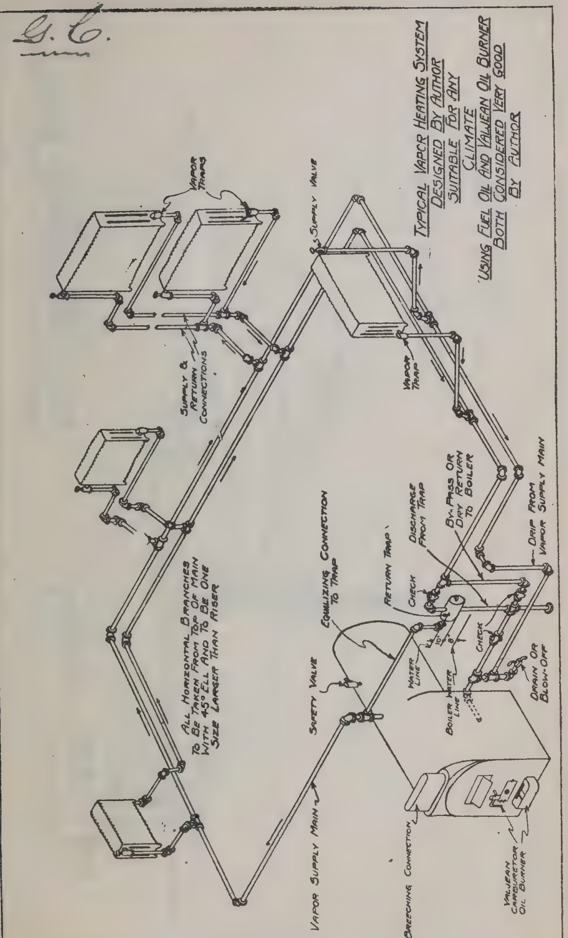

NEUTRAL
VACUUM.
PRESSURE
3
1
2
14
4
5
10
11
13
12
A
C
7
6
9
D
E
G
B
F
8
15
15
14

1. NEUTRAL OR AIR VENTING POSITION-
VALVES OPEN.

2. VACUUM RETAINING POSITION. VAC. V. CLOS'D.

3. PRESSURE OR EQUALIZING POSITION.—
CONDENSATION RETURN VALVE CLOSED.

1 VACUUM RETAINING VALVE
2 CONDENSATION RETURN "
3 DUST CAP AND TOP ALIGNMENT.
4 COMPOUND VALVE SEATS.
5 VALVE BONN. & GUIDE
6 FLOAT ARM BAR.
7 VALVE STEM YOKE
8 5" COPPER FLOAT.
9 BRASS AIR ELIMINATING & BALANCE PIPE.
10 COUPLING.
11 MAIN TRAP CASTING
12 FLOAT CHAMBER & VACUUM WATER CHAMB
13 GASKET
14 "
15 DRAIN PLUGS.


G. C.

TYPICAL VAPCR HEATING SYSTEM
DESIGNED BY AUTHOR
SUITABLE FOR ANY
CLIMATE
USING FUEL OIL AND VALJEAN OIL BURNER
BOTH CONSIDERED VERY GOOD
BY AUTHOR

VAPOR TRAPS
SUPPLY VALVE
SUPPLY & RETURN CONNECTIONS
VAPOR TRAP
ALL HORIZONTAL BRANCHES TO BE TAKEN FROM TOP OF MAIN WITH 45° ELL AND TO BE ONE SIZE LARGER THAN RISER
EQUALIZING CONNECTION TO TRAP
RETURN TRAP
DISCHARGE FROM TRAP
BY-PASS OR DRY RETURN TO BOILER
CHECK
CHECK
DRIP FROM VAPOR SUPPLY MAIN
SAFETY VALVE
WATER LINE
10"
8"
BOILER WATER LINE
DRAIN OR BLOW-OFF
VAPOR SUPPLY MAIN
BREECHING CONNECTION
VALJEAN CARBURETOR OIL BURNER

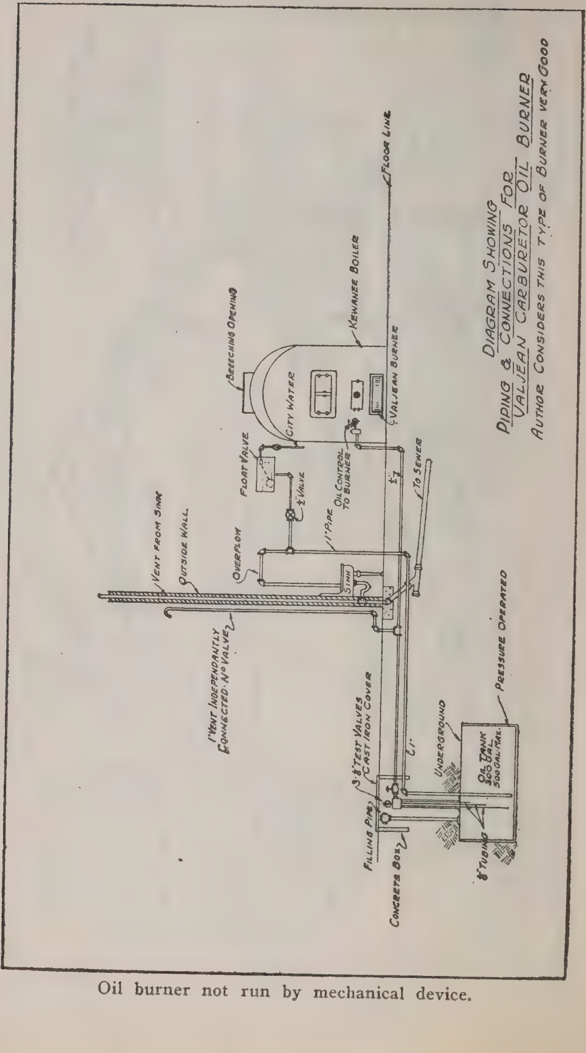
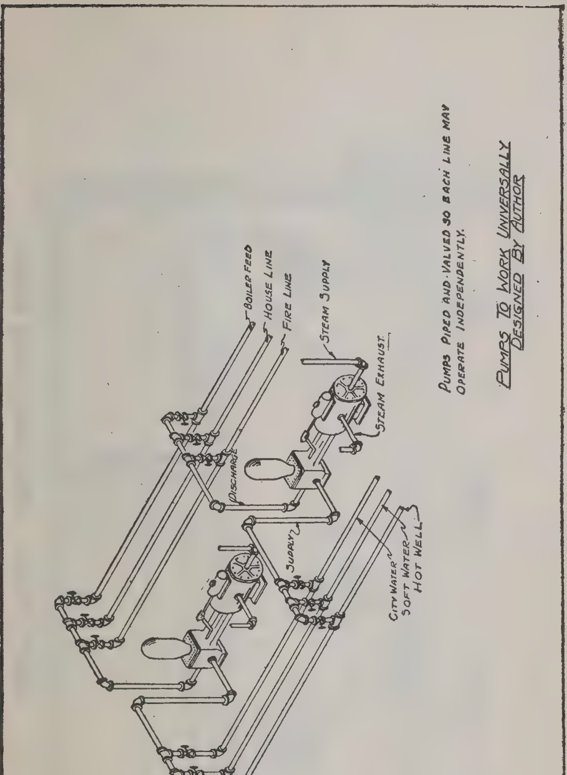
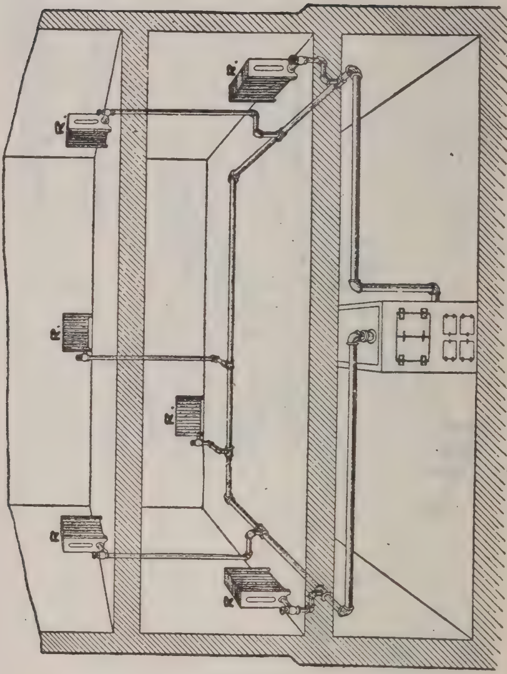


DIAGRAM SHOWING
PIPING & CONNECTIONS FOR
VALJEAN CARBURETOR OIL BURNER
AUTHOR CONSIDERS THIS TYPE OF BURNER VERY GOOD
FLOOR LINE
KEWANEE BOILER
BREECHING OPENING
CITY WATER
VALJEAN BURNER
FLOAT VALVE
½" VALVE
OIL CONTROL TO BURNER
1½"
TO SEWER
1" PIPE
OVERFLOW
VENT FROM SINK
OUTSIDE WALL
SINK
1" VENT INDEPENDANTLY CONNECTED · NO VALVE
3-⅛" TEST VALVES
CAST IRON COVER
1"
PRESSURE OPERATED
UNDERGROUND
OIL TANK 300 GAL 500 GAL·MAX.
FILLING PIPE
CONCRETE BOX
⅛" TUBING

Oil burner not run by mechanical device.


BOILER FEED
HOUSE LINE
FIRE LINE
STEAM SUPPLY
STEAM EXHAUST.
STEAM
DISCHARGE
SUPPLY
CITY WATER
SOFT WATER
HOT WELL
PUMPS PIPED AND VALVED SO EACH LINE MAY OPERATE INDEPENDENTLY.
PUMPS TO WORK UNIVERSALLY DESIGNED BY AUTHOR

Typical method of connecting plunger using one valve for three water supplies.



ONE PIPE STEAM SYSTEM.

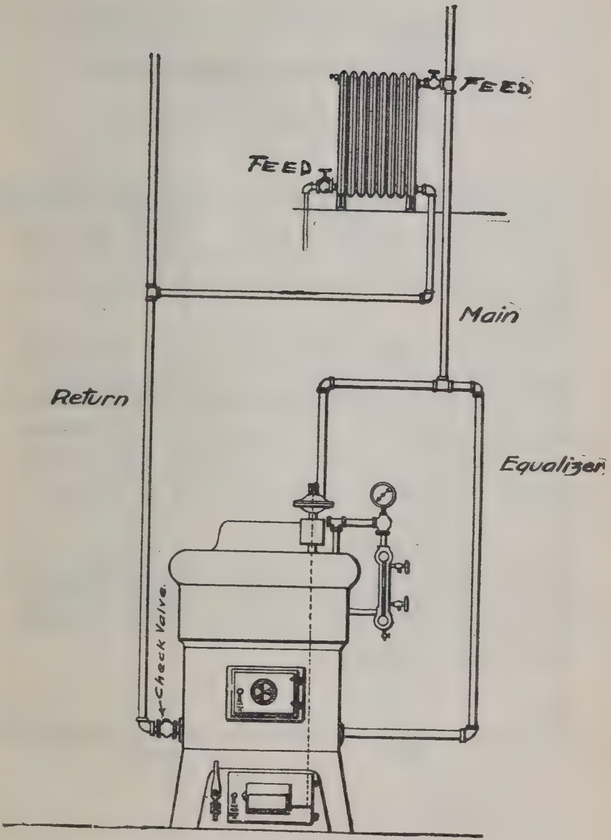

FEED
FEED
Main
Return
Equalizer
Check Valve

Fig. C.

Typical Connection for Steam Heating

CONNECTIONS FOR STEAM HEATING

Fig. C shows the proper way to connect up a cast iron boiler for steam illustration shows both one and two-pipe system. Follow these rules and you will not have any trouble with water in the radiators.

Always take the supply pipe off the top of the Equalizing pipe; nipple should be long enough to give water a fair chance to get back into the boiler, thereby getting dry steam through the entire system.

Fig. D shows a system of overhead force circulation of hot water laid out and done by the author of this book in a foreign country where 18 to 20 inches was the depth on account of surface water. The illustration is just a small sketch showing just how the system was installed, using two pumps operated by electricity, and had twelve thousand square feet of radiation.

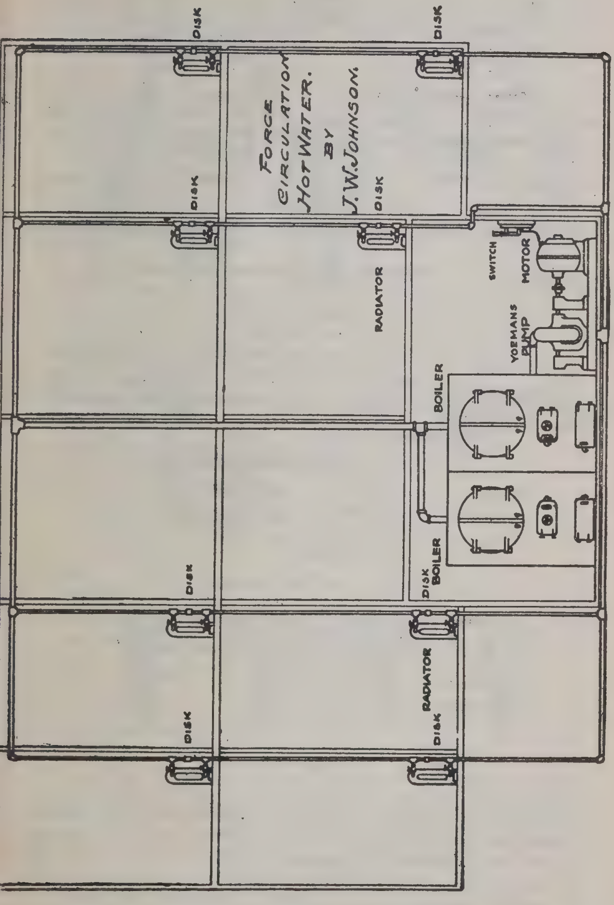

DISK
DISK
FORCE
CIRCULATION
HOT WATER.
BY
J.W. JOHNSON.
DISK
DISK
SWITCH
MOTOR
RADIATOR
YOEMANS
PUMP
BOILER
DISK
BOILER
DISK
DISK
RADIATOR
DISK
DISK

Fig. D.

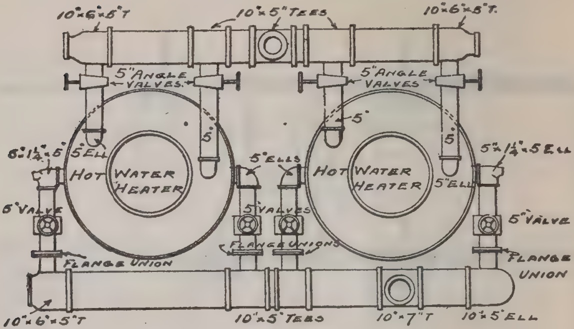

10"×6"×5"T
10"×5" Tees
10"×6"×5"T.
5" Angle Valves.
5" Angle Valves
5"
5
5
6"×1¼"×5"
5 Ell
Hot Water Heater
5" Ells
Hot Water Heater
5" Ell
5"×1¼"×5 Ell
5" Valve
5" Valves
5" Valve
Flange Unions
Flange Union
Flange Union
10"×6"×5"T
10"×5" Tees
10"×7"T
10"×5" Ell

Fig. E.

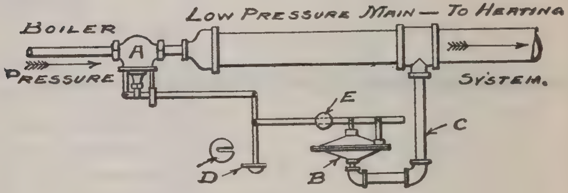

Boiler
Pressure
A
Low Pressure Main — To Heating System.
E
C
D
B

Fig. F.

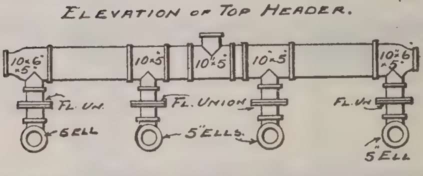

Elevation of Top Header.
10×6 ×5
10×5
10×5
10×5
10×6 ×5
Fl. Un.
Fl. Union
Fl. Un.
6 Ell
5" Ells
5 Ell

Fig. G.

Fig. E is a plain view of a couple of Hot Water Heaters,—twin connection. The size of pipes, valves and fittings are given merely to illustrate the difference in sizes. Actual sizes of pipes, etc., are, of course, governed by size of heaters. As there is not much expansion in water the header should be of an area equivalent to the area of the connections to the heaters. For the same reason the return header and connections to heaters should be of the same size as the supply. The illustration shows headers to be 10″ diam. with four 5″ connections to heaters. Area of one 10″ pipe being equal to the area of four 5″ pipes. The illustration is so plain that any steamfitter will readily understand it.

Where steam for heating purposes is taken from a power boiler, we must employ a reducing valve. Boiler pressure might be from 80 to 120 pounds. To reduce and admit steam to the heating main at any pressure wanted, the apparatus shown in the illustration, Fig. F, is employed.

A is a throttle valve, B diaphragm, C connection between low pressure main and diaphragm—D and E are counter weights. By moving D towards or away from the diaphragm and taking off or putting on weights at D, the pressure in low pressure main can be reduced to any pressure wanted. The working is as follows: Steam is admitted through the throttle valve to the low pressure main until the pressure in the main is of the number of pounds to which the apparatus is set. Then the steam from the low pressure main acts on the diaphragm and, through the levers, partly closes the throttle valve. A diaphragm, being very sensitive, keeps steam in the heating main at the pressure wanted, at all times.

Fig. H is a plain view of a couple of steam generators,—twin connection. The size of pipes and fittings are given merely to illustrate the difference in sizes. Actual sizes of pipes are, of course, governed by the size of generators required. Fig I is a side elevation, on larger scale, showing steam and return pipes—from the 6″ Tee, Fig. H, with outlet looking up, connection is made to one or more loops of the supply line. Return to boilers is made at the 6″x6″ Tees. Close to the Tees, for the supply as well as for the return connections, flange unions should be inserted so that disconnection of boilers can be made without breaking a fitting.

The advantage of two boilers is: that in Spring and Fall, when just a little heat is required, one boiler only needs to be in use, thereby saving in fuel.

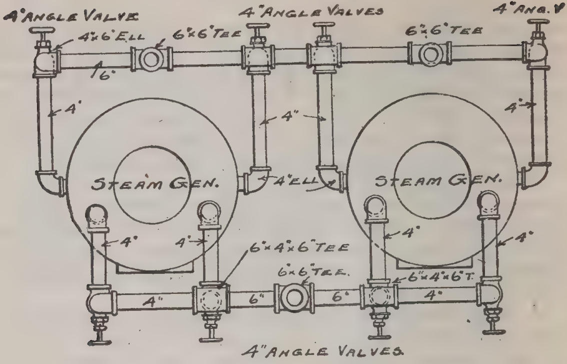

4" ANGLE VALVE
4"x6" ELL
6"x6" TEE
4" ANGLE VALVES
6"x6" TEE
4" ANG. V
6"
4"
4"
4"
STEAM GEN.
4" ELL
STEAM GEN.
4"
4"
4"
4"
6"x4"x6" TEE
6"x6" TEE.
6"x4"x6" T.
4"
6"
6"
4"
4" ANGLE VALVES.

Fig. H.

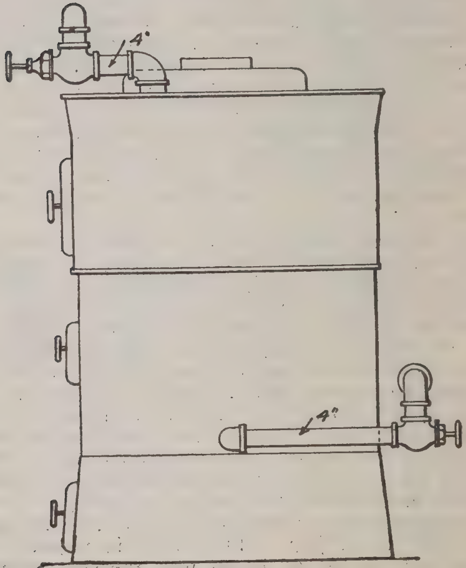

4"
4"

Fig. I.

The S. R. System of Steam Heating

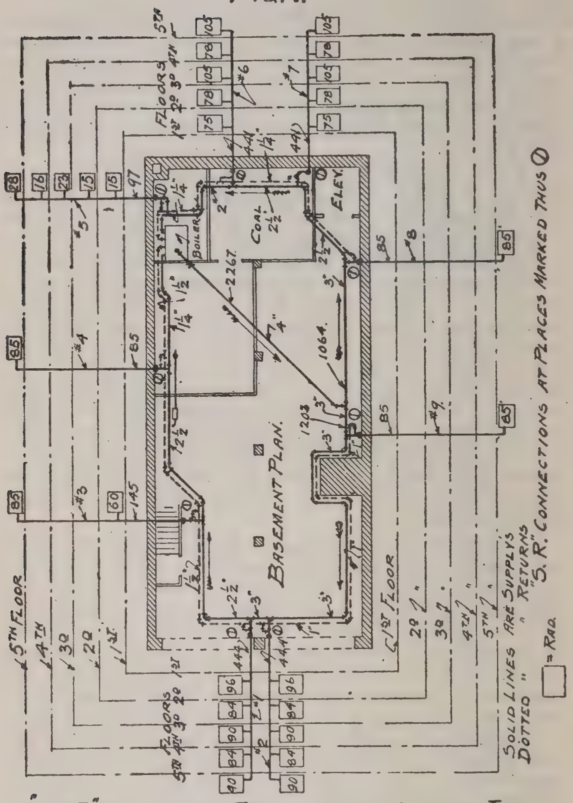
The drawing marked Figure 1 shows a layout of a modified one pipe piping system for a steam heating plant. In regular one pipe systems the condensation returns to the supply main and naturally has a tendency to saturate the steam in the main with water, thereby reducing its temperature.

In this plan which has 2267 square feet of radiation, and which is heating to 70 degrees at 0, it is fair to assume ⅓ pound condensation per square foot per hour, the supply and return mains being uncovered. On this basis 755 pounds of water or 90 gallons will have to pass through the supply main every hour. It is true that this water before it reaches the boiler will be nearly at steam temperature, but this is no place to make the steam as the boiler itself is better adapted to this purpose. By the use of this system it will be seen that the only water in the supply main is that which is created on account of its own surface, and all other condensation, from radiators, risers and branches are arrested at the S. R. fitting and returned directly to the boiler without in any way affecting the generated steam.

The condensation element being removed from the supply main naturally increases its capacity for supplying steam. Consequently where (in this building) a 5 inch supply pipe would be used a 4 inch was put in; this 4 inch was an error as the main shown should have been 3½ inch. This then would mean a 3½ inch main and a 1½ inch return, each pitching in the same direction and carried on the same set of supports. The branch from main to riser will always be as shown, one size smaller than the riser or branch up to the tee that contains the S. R. fitting, as it is obvious the branch to this point is only a supply and is not concerned in the matter of condensation.

Since the water is removed from the supply mains and a drier steam is produced, a great many of the present air valve troubles should be overcome.

FIG. 1.


BASEMENT PLAN.
COAL
BOILER
ELEV.
5TH FLOOR
4TH
3D
2D
1ST
1ST FLOOR
2D
3D
4TH
5TH
FLOORS 1ST 2D 3D 4TH 5TH
FLOORS 5TH 4TH 3D 2D 1ST
#1
#2
#3
#4
#5
#6
#7
#8
#9
2267
1064
1203
85
97
145
SOLID LINES ARE SUPPLYS
DOTTED " " RETURNS
"S. R." CONNECTIONS AT PLACES MARKED THUS ①
☐ = RAD.

"S. R." SYSTEM OF PIPING FOR STEAM JOB.

A further development of the system also includes a return riser connecting with the return main shown, in this case not only using the S. R. fitting in the branch shown, but on the branch from the riser to the radiator as well. Then all of the condensation in the system will be returned separately and no condensation from radiation will pass through risers.

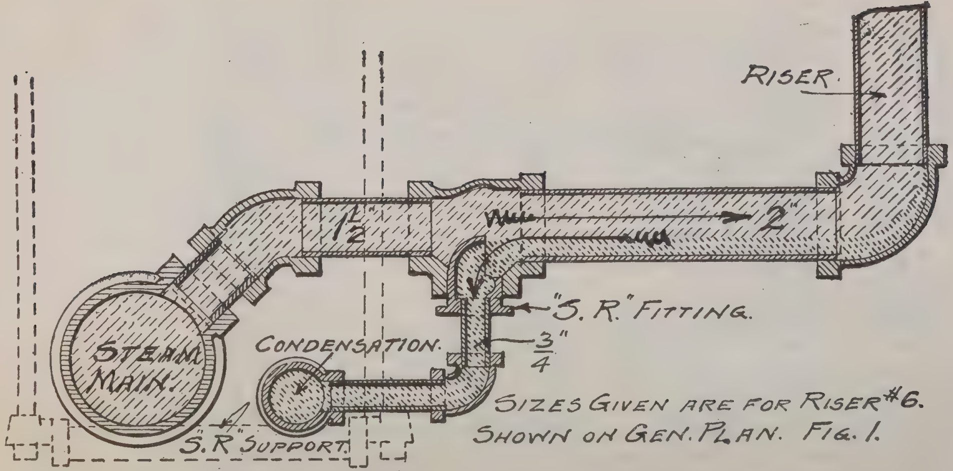
The sizes of risers proper will not change on plan marked Figure 1 as this is still a regular one pipe condition, while if an S. R. fitting is also used from the branch to the radiator as well, then, as mentioned before, no condensation from radiators will pass through the risers and all supply branches and risers will be reduced one pipe size or more, depending on the refinements of general layout.

This system will have the effect of reducing the piping losses to the extent of decreasing the boiler capacity and a consequent more economical condition.

Cost of installation should be about the same as a standard one pipe system, as the use of smaller pipes and apparatus will offset the apparent additional cost entailed in the S. R. way. The item of labor on piping on the job shown in Figure 1 seemed if anything to be a little easier than a regular one pipe main, the mechanic on the job saying he would rather any time run a 3½ inch and 1½ inch pipe than one 5 inches, and that he would surely prefer to cut and fit 1½ inches instead of 2 inch pipe.

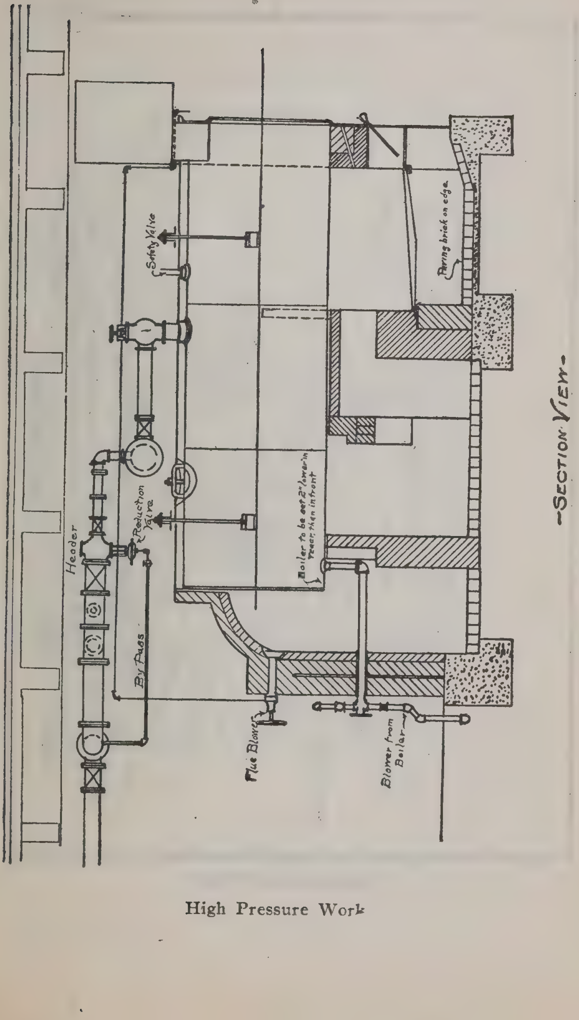
The effect of insulating covering on this S. R. job will be of greater importance than on the other type, because each line, whether feed or return will carry its own special substance, each of which is well worth being conserved and neither of which gives or takes from the other. In substance a real supply pipe and an independent and positive return.

FIG 2.

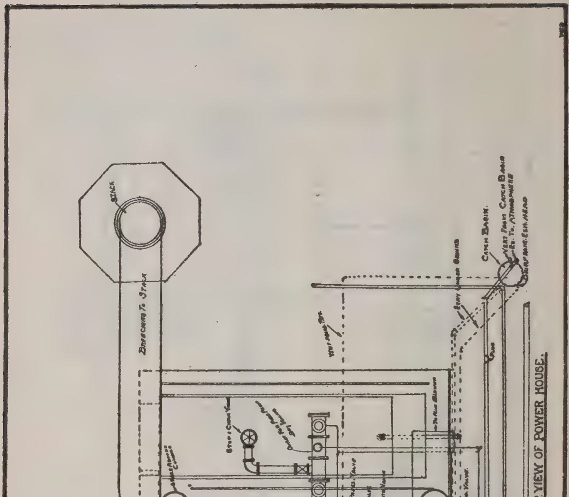

RISER.
2"
1 1/2"
"S. R." FITTING.
3/4"
CONDENSATION.
STEAM MAIN.
"S. R" SUPPORT.
SIZES GIVEN ARE FOR RISER #6.
SHOWN ON GEN. PLAN. FIG. 1.

The S. & R Fitting is the most practical device ever produced for the heating trade.

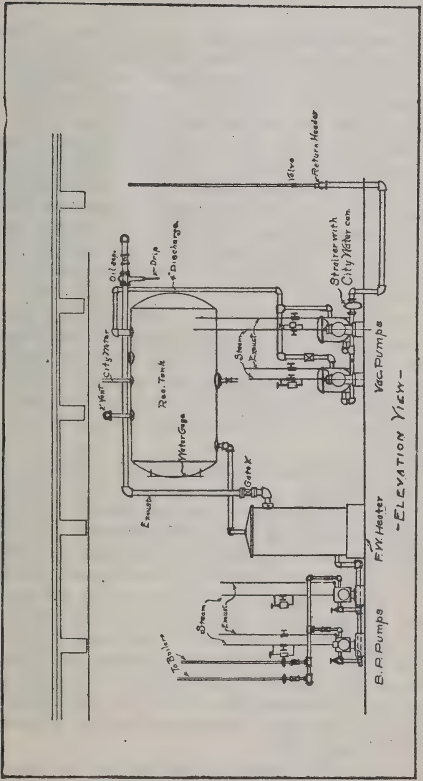
This fitting converts a one pipe system into a two pipe system in the most practical manner and eliminates all air binding and other troubles which naturally come with the one pipe system.


Header
Reduction Valve
By Pass
Safety Valve
Paving brick on edge
Boiler to be set 2" lower in rear, than in front
Flue Blower
Blower from Boiler
-SECTION VIEW-

High Pressure Work


TOP VIEW OF POWER HOUSE.
STACK
BREECHING TO STACK
CATCH BASIN.
GATE VALVE
STOP & CHECK VALVE
STOP CHECK VALVE
GATE VALVE
300 HP WEBSTER F.W. HEATER
MASON B.P. PUMP
RETURN
AIR TANK
AIR COMPRESSOR

High Pressure Work


Return Header
1½ Glve
Strainer with City Water con.
Oil sep.
Drip
4" Discharge
City Water
2" Vent
Rec. Tank
Water Gage
Steam
Exaust
Vac. Pumps
Gate V
Exaust
F.W. Heater
-ELEVATION VIEW-
Steam
Exaust
To Boiler
B.F. Pumps

High Pressure Work

Water Line Troubles in Steam Boilers.

One of the common causes of water line trouble in steam boilers is insufficient distance between the normal water line of the boiler and the dry return to take care of the inequality in pressure in the heating system.

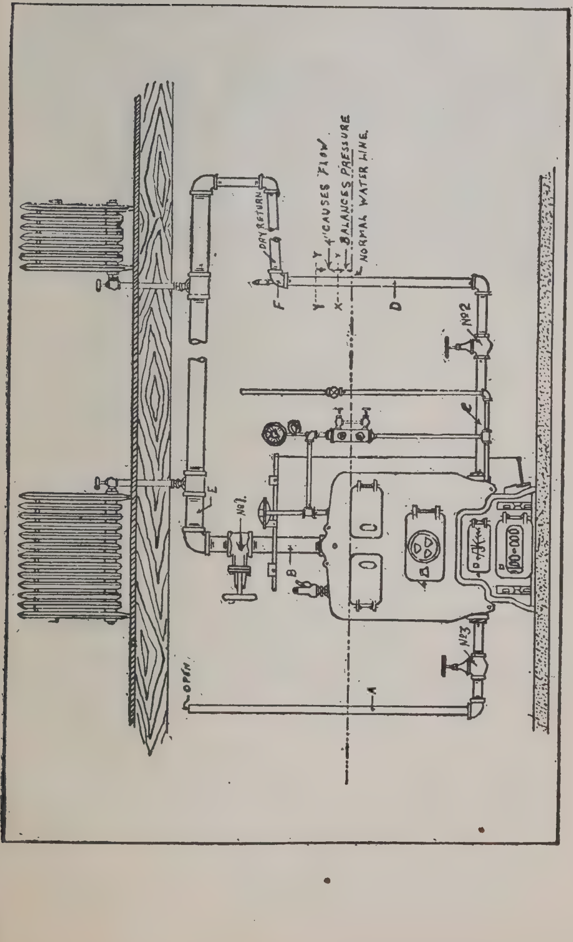
In the accompanying cut, if the boiler is filled with water to normal water line at center of gauge glass; valves Nos. 1 and 2 are closed, and No. 3 opened, the water will stand in the open pipe "A" at the same height as the water in the boiler.

If a fire is built in the boiler, the steam generated being unable to escape through the pipe "B" will accumulate a pressure which will raise the water in the pipe "A." As the pressure increases the water in the vertical pipe "A" will be raised until the static head of water balances the steam pressure. Every pound of pressure generated will raise the water in the pipe "A" approximately 28″. If the steam pressure were raised high enough the water would be driven out of the top of the vertical pipe.

In an enclosed steam heating plant a similar condition exists, the water in the vertical return pipes balancing the difference in pressure created by the condensation of the steam and pressure loss due to friction.

If the valves 1 and 2 are opened, and No. 3 closed the water stands in the return pipe "D" at the normal water line level; when steam is formed in the boiler it flows through the vertical pipe "B" and is distributed to the radiators through the horizontal pipe "E." As the steam is condensed its pressure is lost. The frictional loss due to the steam passing through fittings and pipe always causes a drop in pressure, and if the pipe "E" is long, or too small this loss in pressure becomes a very important consideration and, added to the natural drop in pressure due to the condensing of the steam, results in a material difference in pressure in the system at the points "B" and "F."

As an example, assume that the steam supply main "E" is 125 feet long, and its size has been determined to allow for a pressure drop of 3 ounces. When the steam gauge on the boiler registers two pounds, a steam gauge if placed at "F" would show 29 ounces, and to equalize this difference in pressure


DRY RETURN
4" CAUSES FLOW
BALANCES PRESSURE
NORMAL WATER LINE
Y
Y
X
F
D
No2
C
E
No1
B
No3
A
OPEN

the water in pipe "D" would be raised approximately 5¼ inches (1.732 inches per ounce) to a line indicated by X—X′.

Water standing at the height X—X′ represents balanced pressures in the system. However, as steam is condensed, it is necessary to return to the boiler the water accumulating in the pipe "D." To do this the pressure in pipe "D" must exceed the pressure in the boiler, requiring an additional 4 inches of head, making total elevation of 9¼ inches in the return, as indicated by the line Y—Y′.

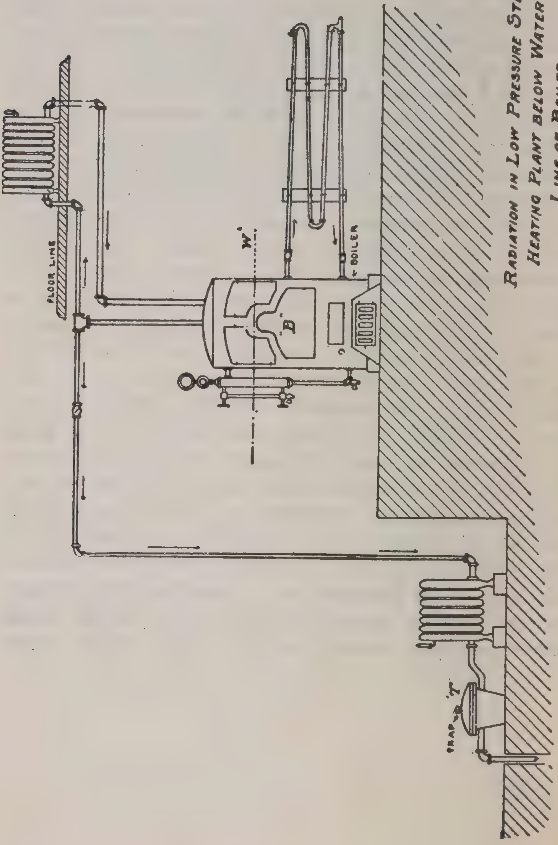
On account of the high frictional loss often found and increased pressure drop when system is first heating, it is advisable to maintain a distance of at least 18 inches between the normal water line and the point "F," which is the low point of the dry return.

Radiation in Low Pressure Steam Heating Plant Below Water Line of Boiler.

There are two ways by which heat may be had from low pressure steam heating plants at points below the water level of the boiler, and while these two special points are known to the average fitter, there are many persons practicing this line of trade who have had no experience with such system, but who often meet situations where radiation below the water line would be desirable. The illustration, Fig. 8, will serve to show how the pipe work of such radiation may be practically carried out. In the illustration B represents the steam boiler, from which steam may be carried to the various radiators situated above the boiler and having the usual return pipe to bring back the condensation to the boiler.

The highest point to which water rises, or the water level, is indicated by W, and on the right side of boiler is a return bend coil, all of which is situated below the water level, and which can be used as radiating surface. Through this coil the water from the steam boiler can be made to circulate, and will be found to be very effective. Both connections of the coil should be provided in such cases with valves as shown, and while one valve would answer the purpose of stopping the circulation, it is always best to provide against a leak in the coil, so that a valve in each branch to the boiler might save

Radiation in Low Pressure Steam Heating Plant Below Water Line of Boiler.


FLOOR LINE
W'
B
BOILER
TRAP
T

Radiation in Low Pressure Steam Heating Plant below Water Line of Boiler.

Fig. 8.

trouble and annoyance. Then where such radiation as shown on the right of boiler is used, provision should always be made to drain the coils of water when not wanted for heating purposes in cold weather, and this can be done by placing a pet cock at some point on the lower pipe in such coil. If the pipes to hot water radiation of this kind are carried as shown, there will be no necessity of air valves, as all air will pass to the boiler and escape through radiators situated at some higher elevation.

Any style of hot water radiation can be used for such purposes, as well as pipe coils, by simply carrying out the same general principle of producing circulation. On the left of the boiler in the illustration is shown another kind of radiation at a point below the boiler, and in this case steam is used, but the condensation does not return to the boiler, and therefore provision is made in this case so that there will be no escapement of steam and at the same time completely draining the radiator. At the outlet end of this style radiation is placed a steam trap, as indicated by T, the discharge pipe from which connects with a waste or drain pipe. There are a few special points connected with this arrangement of radiation, which must also be remembered, to guard against damage from freezing. And, as will be noticed, the radiation is elevated so that all water will fall from it into the steam trap by gravitation, then, again, the one valve for controlling the supply of steam to this radiator is located near the main steam pipe above the boiler, so that at times when this valve is closed there will be no chance for water to stand in any part of the steam pipe to the radiator where it might freeze. An automatic air valve will be necessary on such radiators in order to keep up a circulation of the steam at all times during cold weather, for the reason that it would be possible to stop circulation by the accumulation of air in the radiator with an ordinary direct air valve, and with the steam supply valve on main pipe wide open, and under such circumstances it would be possible for the water to freeze in the steam trap, thus closing the outlet and allowing the radiator and all connections to it to fill with water. Therefore it will be seen that this is a very important place to use the best make of automatic air valves. In regard to the supply valves on all lines, if globe valves are used, they should be placed at an angle of 45 degrees, as shown in illustration, in order to prevent trapping of these lines, but gate valves in such places may be placed at any angles. In heating systems of this kind where steam radiation is located below the water level of the boiler and condensation from such surface discharged through steam traps, there will be a loss of water from the boiler to the extent of such condensation, and on this account, it will be necessary to place on the boiler a reliable automatic water feeder connected to the water service supply to keep the water up to its proper height in the boiler at all times, and not alone to save attention but to protect the boiler.

What a Unit of Heat is.

A unit of heat is that amount of heat which is required to raise the temperature of one pound of water 1 degree F., and is used to calculate and measure the quantity of heat.

Combustion of Fuel in House-Heating Boilers.

The combustion of fuel in any given area of grate must depend on the rapidity of the draught.

In ordinary home heating boilers, one square foot of grate will burn from 5 to 8 pounds of coal per hour.

One pound of coal should add about 9000 heat units to water in a boiler used for heating purposes.

One cubic foot of ordinary coal gas contains 650 units of heat, but 50% of this is lost in the generating of steam or heating of water by even the best construction of Bunsen or atmospheric burners, so that 1 cubic foot of 16 candle power gas will add about 325 units of heat to water below 200 degrees F.

A most important thing in the construction of steam heating plants, is to properly proportion the boiler, the grate surface with the heating surface, also the proper area of chimney for a proper and economical consumption of the fuel, and for this purpose the diagrams on page 38 have been arranged, and which are the result of practical experience and tests under various conditions.

It will be noticed in referring to plate, Fig. 9, that one square foot of grate surface will supply 36 square feet of boiler surface; and this amount of grate and boiler surface will carry 196 square feet of direct radiating surface for heating purposes. The area of chimney must be taken into consideration, and for this amount we allow 49 square inches.

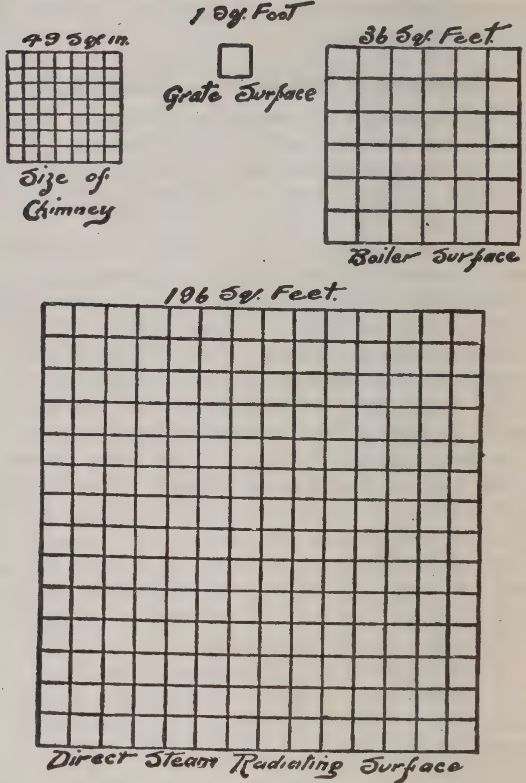

1 Sq. Foot
49 Sq. in.
36 Sq. Feet.
Grate Surface
Size of Chimney
Boiler Surface
196 Sq. Feet.
Direct Steam Radiating Surface

Fig. 9

Table Showing Sizes of Chimneys with Approximate Horse Power Boilers.

Diameter in Inches.	HEIGHT OF CHIMNEYS. 50 ft.	60 ft.	70 ft.	80 ft.	90 ft.	100 ft.	110 ft.	125 ft.	150 ft.	175 ft.	200 ft.	Effective Area, Square Feet.	Actual Area, Square Feet.	Size of Square of Approximate Area, Inches.
	COMMERCIAL HORSE POWER.													
18	23	25	27	....	....	....	....	....	....	....	....	0.97	1.77	16
21	35	38	41	....	....	....	....	....	....	....	....	1.47	2.41	19
24	49	54	58	62	....	....	....	....	....	....	....	2.08	3.14	22
27	65	72	78	83	....	....	....	....	....	....	....	2.78	3.98	24
30	84	92	100	107	113	....	....	....	....	....	....	3.58	4.91	27
33	....	115	125	133	141	....	....	....	....	....	....	4.47	5.94	30
36	....	141	152	163	173	182	....	....	....	....	....	5.47	7.07	32
39	....	....	183	196	208	219	....	....	....	....	....	6.57	8.30	35
42	....	....	216	231	245	258	271	....	....	....	....	7.76	9.62	38
48	....	....	....	311	330	348	365	389	....	....	....	10.44	12.57	43
54	....	....	....	363	427	449	472	503	551	....	....	13.51	15.90	48
60	....	....	....	505	539	565	593	632	692	748	....	16.98	19.64	54
66	....	....	....	....	658	694	728	776	849	918	981	20.83	23.76	59
72	....	....	....	....	792	835	876	934	1023	1105	1181	25.08	28.27	64
78	....	....	....	....	....	995	1038	1107	1212	1310	1400	29.73	33.18	70
84	....	....	....	....	....	1163	1214	1294	1418	1531	1637	34.76	38.48	75
90	....	....	....	....	....	1344	1415	1496	1639	1770	1893	40.19	44.18	80
96	....	....	....	....	....	1537	1616	1720	1876	2027	2167	46.01	50.27	86

Chimney Flues.

For low pressure gravity steam heating plants, carrying over 1000 feet of radiation, the size of chimney may be reduced somewhat less in proportion than that shown in Fig. 9. The success of any heating plant depends largely on the chimney, and no matter how well a boiler may be proportioned and constructed, there cannot be proper results unless the chimney is also properly constructed. Chimneys intended for heating plants should never be constructed less than 8x8 inches in the clear for the smallest size private house.

Size of Flues for Indirect Radiation.

Heating Surface, Sq. Ft.	Area of Cold Air Supply, Sq. In.	Area of Hot Air Supply, Sq. In.	Size of Brick Flue for Hot Air.	Size of Register.
20	30	40	4x12	8x 8
30	45	60	8x12	8x12
40	60	80	8x12	10x12
50	75	100	12x12	10x15
60	90	120	12x12	12x15
80	120	160	12x16	14x18
100	150	200	12x20	16x20
120	180	240	14x20	16x24
140	210	280	16x20	20x24

OVERHEAD SYSTEM OF STEAM HEATING

Showing Cranetilt Traps Draining the Various Equipment and Supplying the Boilers With Feed Water.

The installation of traps in plants on power heating and process work tend toward the conservation of energy and a more efficient and economical operation of the various equipment.

There are three types: Non-return, Direct Return and Three-valve Lifting Trap.

The Non-return handles condensation and discharges to any receptor. Does not discharge to the boiler.

The Direct-return Trap receives condensation and returns the hot water to the boiler at any temperature and pressure.

The Three-valve Trap may be used as a lifting trap on any system where the condensation pressure is above atmosphere, as a vacuum trap to remove condensation under vacuum without destroying the vacuum and as a metering trap when equipped with a counting device.

The general application of traps is shown on this diagram. Crane Co. has an engineer in each of their branches who can advise you as to special application.

Item No. 11 shows the installation of a Direct-return Trap and receiver which receives the condensation from the several sources and returns the hot water under any temperature to the boiler.

In all Direct-return Trap installations there are a few suggestions as to piping the equipment to obtain the best results.

First the Direct-return Trap should be located at least 4′ 0″ above the water level in the boiler and if there is more height available the better. The receiver should be located not less than 12″ above the top of the Direct-return Trap tank in the filling position; higher will give better and slightly quicker operation. When you install inlet pipe No. 29 to the Direct-return Trap and have a low filling head, it is well to increase pipe No. 29 one size larger than the pipe size of the trap.

Receiver No. 35 should be of ample capacity to serve the Direct-return Trap. Inlet pipe No. 29 should be run up inside of receiver No. 35 to maintain the receiver one-third full of condensation so that vent No. 31 from trap will always be buried under the water. See that two small ¼" holes are drilled in vent pipe No. 31 just inside near top of shell of receiver No. 35. Provide pop valve No. 36 to protect the receiver from overpressure, also air valve No. 27 to take care of the venting of receiver. Install all check valves on horizontal runs, provide gate valves on all lines except the steam line to traps which should be of the globe type. Install ground joint unions on all connections to make the equipment accessible for repairs. Install sediment trap No. 30 on all trap inlet lines providing a drain valve on each sediment trap.

In general, when installing steam traps see that they are low enough so that the condensation will flow readily to them and that the traps are set perfectly level. Make piping connections so that the trap will not be unduly strained due to the expansion and contraction of the piping.

Item No. 5 shows Cranetilt Non-return Trap draining steam line No. 16 and steam separator on engine lead No. 2. Two points can be connected into one trap as in this case where there is a difference in head to overcome a difference in pressure that might exist on the inlet to the trap.

A better practice is to install a separate trap on each drain point to be served to avoid all liability of the above mentioned possibility.

Item No. 6 shows Cranetilt Three-valve Trap draining an oil separator No. 4. The discharge No. 20 of this trap should go to sewer, and vent No. 21 from trap should go back into line No. 3 with check and gate valve near line No. 3.

Item No. 8 shows lifting trap taking water from feed water heater and supplying make-up water to receiver above the direct return trap. A throttle valve on the steam to the trap No. 8 should be controlled by a float located in receiver No. 35 which maintains water in receiver No. 35 at all times.

Item No. 9 shows lifting trap connected to receiver No. 25 which receives condensation from the heating returns No. 26. Several No. 26 lines can be connected into receiver No. 25 but they must be supplied with a check valve at receiver. Receiver No. 25 should be of ample size so that returns will always be comparatively free of condensation.

Item No. 10 shows Cranetilt Non-return Trap draining manifold header No. 14.

The last but not least thing to do before connecting up any trap or equipment is to see that all the lines are thoroughly blown out with either steam or air pressure and made perfectly clean of all scale, etc.

Stop check valve No. 12 should be properly drained, also any other points in steam system where there is a liability for water to lodge and cause the possibility of a water hammer.

KEY TO DIAGRAM.

1. Steam engine.
2. Steam supply to engine.
3. Engine exhaust.
4. Oil Separator.
5. Non-return trap draining separator and drip pocket.
6. Lifting trap draining oil separator discharging to sewer.
7. Open feed water heater.
8. Lifting trap supplying make-up water to receiver above direct return trap.
9. Lifting trap draining heating system.
10. Non-return trap draining manifold steam header.
11. Direct return trap and receiver feeding boiler.
12. Crane automatic stop check valves.
13. Pressure regulating valve supplying live steam to heating system.
14. Main steam manifold header.
15. Boiler leads.
16. Main steam line.
17. Trap discharge main to receiver.
18. City water line to feed water heater float controlled.
19. Inlet to lifting trap.
20. Discharge from lifting trap.
21. Vent from lifting trap.
22. Live steam to lifting trap.
23. Inlet to non-return trap.
24. Discharge from non-return trap.
25. Receiver above lifting trap.
26. Returns from heating system.
27. Hoffman Return line valves on radiators.
28. High pressure steam to regulator.
29. Inlet to direct return trap.

30. Sediment trap on inlet.
31. Vent from direct return trap to receiver.
32. Return line from traps to feed water heater.
33. Discharge from direct return trap to boiler.
34. Steam direct off of boiler to direct return trap.
35. Receiver above the direct return trap.
36. Pop valve on receiver.
37. Boiler blow off.
38. How to install valve for blow off lines.

Every blow off outlet of each boiler in a battery should be equipped with a blow off cock or a Y blow off valve, between the boiler and the blow off valve.

When blowing off a boiler, the cock or Y valve should be opened first, and the blowing off operation controlled by the blow off valve. When through blowing off, valve should be closed first and then the cock or Y valve.

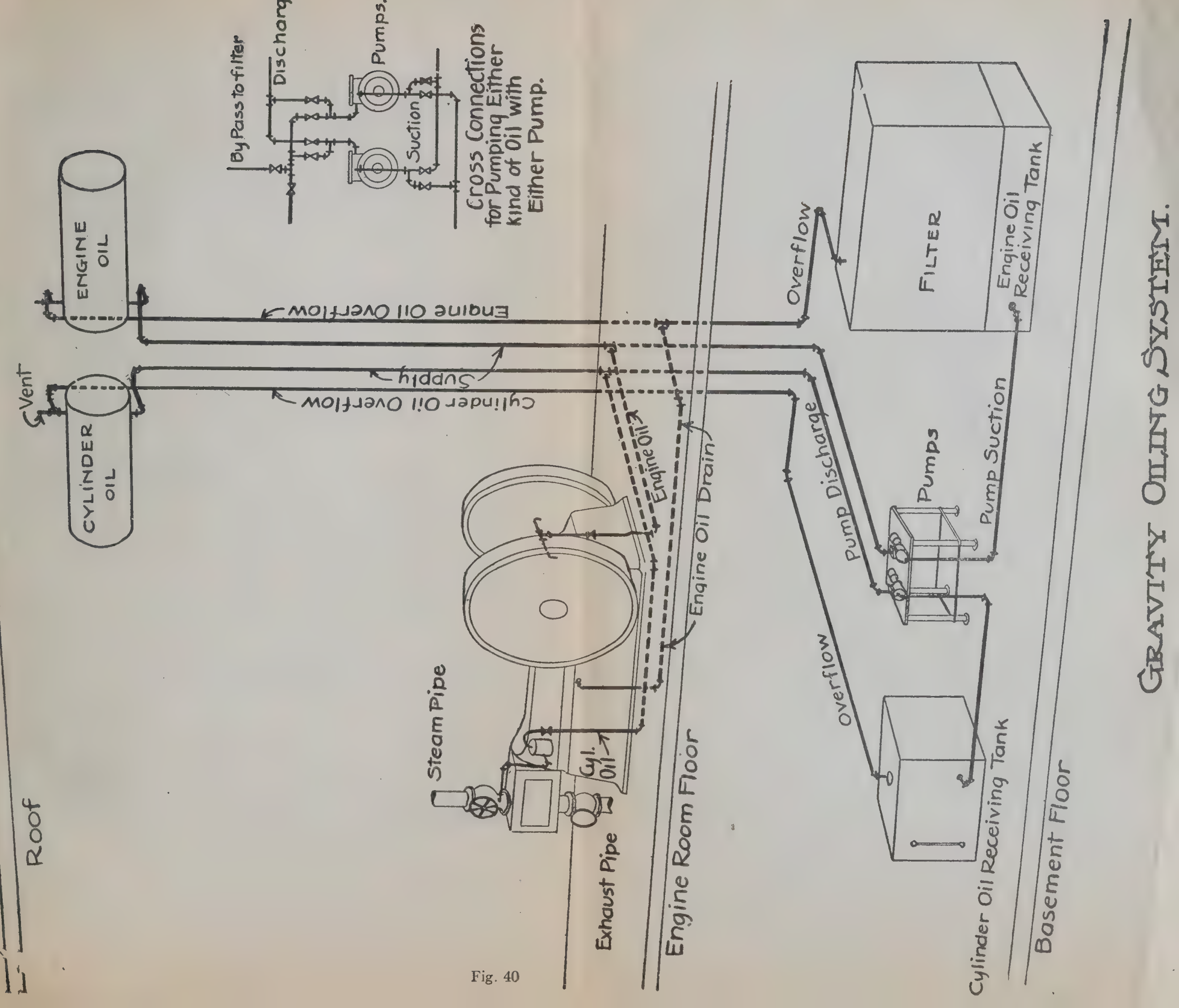
High Pressure Lubricating System.—Fig. 40.

An oil storage tank is placed at a convenient location above the engines and piping from the storage tank run to all bearings which it is desired to oil. A system of piping is also run from pans or bed frames under bearings of engines which catch oil from bearings back to a combined oil filter and storage tank. This latter may be any good make. There are several on the market.

From the outlet opening in this filter and storage tank run a delivery pipe to the first storage tank, placing a small pump on this pipe which will pull oil from the filter and deliver it into the storage tank.

A very satisfactory pump is a hydraulic duplex pump run by city water pressure instead of steam.

The manufacturers of the filters and pumps will give proper sizes and capacities for various sized engines, etc., so that any steam fitter can put in such a system.


Roof
Engine Oil
Cylinder Oil
Vent
Engine Oil Overflow
Supply
Cylinder Oil Overflow
By Pass to filter
Discharge
Pumps.
Suction
Cross Connections for Pumping Either kind of Oil with Either Pump.
Steam Pipe
Exhaust Pipe
Cyl. Oil
Engine Oil
Engine Oil Drain
Engine Room Floor
Overflow
Filter
Engine Oil Receiving Tank
Pump Discharge
Pumps
Pump Suction
Overflow
Cylinder Oil Receiving Tank
Basement Floor

GRAVITY OILING SYSTEM.

Fig. 40

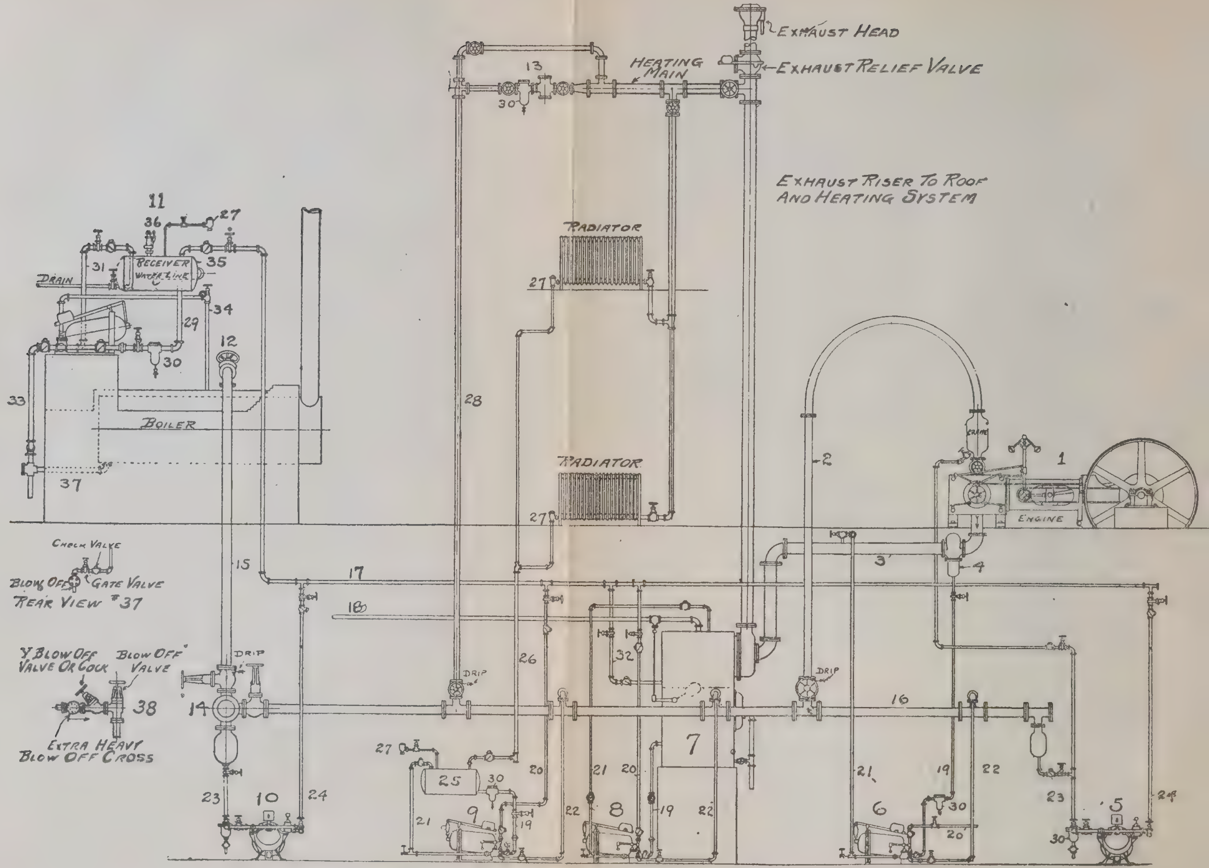

Exhaust Head
Exhaust Relief Valve
Heating Main
13
30
Exhaust Riser To Roof And Heating System
Radiator
27
Radiator
27
28
11
36
27
31
Receiver
Water Line
35
Drain
34
29
30
12
33
Boiler
37
Crane
1
Engine
2
3
4
Check Valve
Blow Off
Gate Valve
Rear View #37
15
17
18
Drip
Y Blow Off Valve Or Cock
Blow Off Valve
38
14
Extra Heavy Blow Off Cross
Drip
26
32
Drip
16
7
27
25
30
20
21
20
9
19
22
8
19
22
21
19
22
6
30
20
23
5
30
24
23
10
24

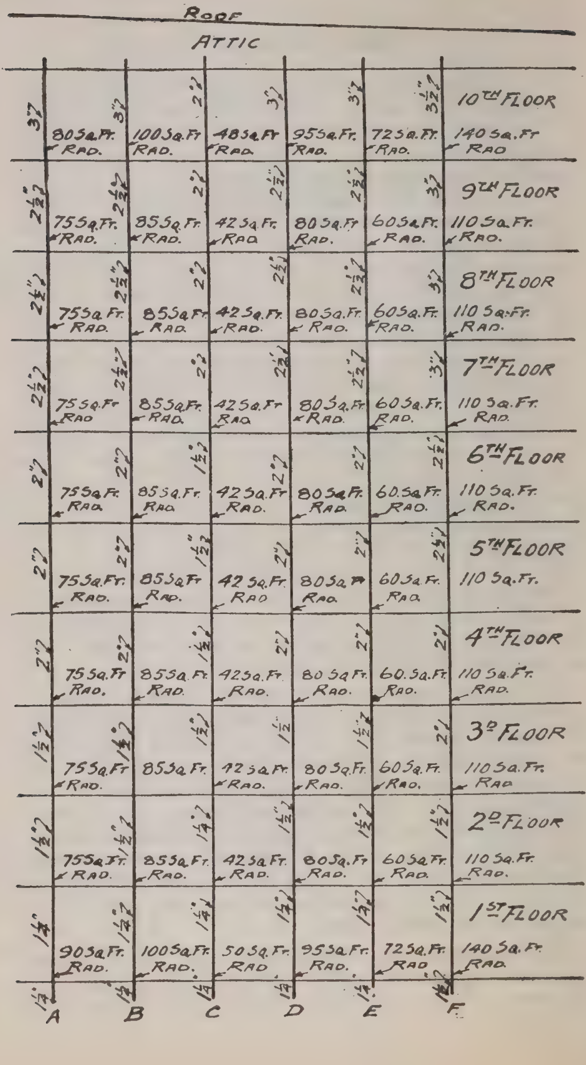
Illustration of Power Plant Equipped with Crane's High Class Specialties.

RISER DIAGRAM.

It is customary and good practice for the heating contractor to prepare a Riser Diagram in addition to the floor plans on which the location and size of radiators are shown. I have prepared a sample, showing how this diagram should be laid out. It is for an overhead one pipe gravity system, and gives the number of square feet of radiation taken off the riser for each floor. It also shows the reduction in the size of riser. The largest size, equal to the area required to supply steam to all the radiators connected to the riser, has to be on the top floor. Reductions can then be made from floor to floor until you get down to the first floor and basement, where the risers usually are from 1¼" to 1½" in diameter. The return, in the ceiling of the basement, ought to be made larger, as this pipe is in a horizontal position, with slower flow and greater friction. On this, what I may call a sample diagram, is shown the risers for a ten story building, and the letters A, B, C, D, E, and F are supposed to correspond with letters marked on the floor plans, where these risers are located. I have taken the number of square feet of radiation off the different risers on each floor at random, merely to show how it should be marked on the diagram. This is also true in regard to the riser.

It is good practice in a gravity system to allow one inch area of pipe for 150 square feet of radiation for risers. Stack "A" supplies a total of 770 square feet of radiation. With one inch area required for every 150 square feet, we find that an area of 5.1 square inches is required at top floor. The nearest pipe size is 3", having an area of 7.38 square inches. This is larger than what is required, but as the next smaller size, viz., 2½", has an area of 4.78 square inches, it is not advisable to use that size; it is better to use the 3" pipe.

To determine the size of the riser on the ninth floor we deduct 80 square feet of the radiation on the tenth floor from the total of 770 square feet,


ROOF
ATTIC
3" 3" 2" 3" 3" 3½"
10TH FLOOR
80 Sq. Ft. Rad.
100 Sq. Ft. Rad.
48 Sq. Ft. Rad.
95 Sq. Ft. Rad.
72 Sq. Ft. Rad.
140 Sq. Ft. Rad.
2½" 2½" 2" 2½" 2½" 3"
9TH FLOOR
75 Sq. Ft. Rad.
85 Sq. Ft. Rad.
42 Sq. Ft. Rad.
80 Sq. Ft. Rad.
60 Sq. Ft. Rad.
110 Sq. Ft. Rad.
2½" 2½" 2" 2½" 2½" 3"
8TH FLOOR
75 Sq. Ft. Rad.
85 Sq. Ft. Rad.
42 Sq. Ft. Rad.
80 Sq. Ft. Rad.
60 Sq. Ft. Rad.
110 Sq. Ft. Rad.
2½" 2½" 2" 2½" 2½" 3"
7TH FLOOR
75 Sq. Ft. Rad.
85 Sq. Ft. Rad.
42 Sq. Ft. Rad.
80 Sq. Ft. Rad.
60 Sq. Ft. Rad.
110 Sq. Ft. Rad.
2" 2" 1½" 2" 2" 2½"
6TH FLOOR
75 Sq. Ft. Rad.
85 Sq. Ft. Rad.
42 Sq. Ft. Rad.
80 Sq. Ft. Rad.
60 Sq. Ft. Rad.
110 Sq. Ft. Rad.
2" 2" 1½" 2" 2" 2½"
5TH FLOOR
75 Sq. Ft. Rad.
85 Sq. Ft. Rad.
42 Sq. Ft. Rad.
80 Sq. Ft. Rad.
60 Sq. Ft. Rad.
110 Sq. Ft.
2" 2" 1½" 2" 2" 2"
4TH FLOOR
75 Sq. Ft. Rad.
85 Sq. Ft. Rad.
42 Sq. Ft. Rad.
80 Sq. Ft. Rad.
60. Sq. Ft. Rad.
110 Sq. Ft. Rad.
1½" 1½" 1½" 1½" 1½" 2"
3D FLOOR
75 Sq. Ft. Rad.
85 Sq. Ft.
42 Sq. Ft. Rad.
80 Sq. Ft. Rad.
60 Sq. Ft. Rad.
110 Sq. Ft. Rad
1½" 1½" 1¼" 1½" 1½" 1½"
2D FLOOR
75 Sq. Ft. Rad.
85 Sq. Ft. Rad.
42 Sq. Ft. Rad.
80 Sq. Ft. Rad.
60 Sq. Ft. Rad.
110 Sq. Ft. Rad.
1¼" 1¼" 1¼" 1¼" 1¼" 1½"
1ST FLOOR
90 Sq. Ft. Rad.
100 Sq. Ft. Rad.
50 Sq. Ft. Rad
95 Sq. Ft. Rad.
72 Sq. Ft. Rad
140 Sq. Ft. Rad.
1¼" 1¼" 1¼" 1¼" 1¼" 1½"
A B C D E F

which gives us 690 square feet, and that divided by 150 gives us the required area, which is 4.6 square inches. Therefore, a 2½" pipe, with an area of 4.78 square inches will be used.

To determine the size of riser on the eighth floor we deduct the radiation taken off on the tenth and ninth floors (which is 80 square feet and 75 square feet, respectively, and equals 155 square feet), from the total of 770 square feet. This leaves us 615 square feet, and that divided by 150 gives us an area of 4.1 square inches. Here again we use a 2½" pipe.

In determining the size of riser on the seventh floor we deduct the amount of radiation taken off from the riser for radiators on the tenth, ninth and eighth floors. For the riser on the sixth floor we deduct radiation taken off on the tenth, ninth, eighth and seventh floors, and continue reducing the area from floor to floor until we finally get to the first floor.

In a vacuum system, whether overhead or not, a return-air riser must be installed. The size will not need to be over ½" pipe at top floor and ¾" half way between the floors. This return air riser should always be smaller at the top floors and larger further down. For a vacuum system it is safe to figure one square inch area of supply riser for 300 square feet of radiation.

A vacuum system is much better than the gravity. The cost is a little more, but not very much. When you take into consideration the perfect way this system operates and the control of the heat, you will find that it is money well spent in installing a vacuum system.

STEAM BOILERS.

Their Construction and Inspection.

The following are extracts taken from the City of Chicago Boiler Inspectors' rules, and will prove of both interest and instruction.

Low Pressure Boiler.

Any boiler for heating purposes only, for which the permit specifies that not more than ten pounds of steam pressure to the square inch shall be carried, shall be known as "low pressure boilers."

Try-Cocks, Gauges and Safety Valves, etc.

Every boiler must have a full complement of try-cocks, one water gauge, one fusible plug of good Banca tin, one or more pop safety valves (the area of pop valves shall be in ratio of one square inch to three square feet of grate surface); direct weighted safety valve may also be used. Boiler shall also be equipped with a suitable shut-off or main stop valve, so placed as to prevent water passing into the heating apparatus during the test made at the time of inspection. There shall also be a good and sufficient force pump or other means of supplying the boiler with water, etc.

Strength of Materials.

Tensile strength of steel plate shall be stamped on plates and shall not be less than 55,000 pounds per square inch.

Strength of Rivets in Shear.

In computing the ultimate strength of rivets in shear, the following values in pounds per square inch of cross-sectional area of rivet shank shall be used: Steel rivets in single shear **44,000**, and steel rivets in double shear **88,000.**

Minimum Thickness of Plates and Tubes.

The minimum thickness of any other plates under pressure shall be ¼″.

The minimum thickness of tube sheets for horizontal return tubular boilers shall be as follows: When the diameter of tube sheet is

42″ or under........⅜″ Over 54″ to 72″....½″
Over 42″ to 54″....7/16″ Over 72″............9/16″

Tubes for Fire Tube Boilers.

The minimum thickness of tubes used in fire tube boilers measured by Birmingham wire gauge, for maximum allowable working pressure not exceeding 175 pounds per square inch, shall be as follows:

Diameter less than 2½″..............No. 13 B. W. G.
Diameter 2½″ or over, but less than 3¼″ ....No. 12 B. W. G.
Diameter 3¼″ or over, but less than 4″ ....No. 11 B. W. G.
Diameter 4″ or over, but less than 5″.No. 10 B. W. G.
Diameter 5″.........................No. 9 B. W. G.

Cylindrical Shells

The maximum pressure to be allowed on a steel or wrought iron shell or drum of a boiler or tank shall be determined from the minimum thickness of the shell plates, the tensile strength stamped thereon, the efficiency of the longitudinal joint or ligament between tube holes (whichever is the least), the inside diameter of the course and the factor of safety. The formula for determining the maximum safe working pressure being as follows:

$$\frac{T\,S \times t \times 0/0}{R \times F\,S} = \text{maximum allowable working pressure pounds per square inch.}$$

T S = ultimate strength stamped on shell plates.
t = minimum thickness of shell plates in inches.
0/0 = efficiency of longitudinal joint or ligament tube holes, whichever is the least.
R = radius—½ the inside diameter of the outside course of shell or drum.
F S = (a) Five for shells not over ten years old.
(b) Five and five-tenths for shells over ten and not over fifteen years old.
(c) Five and seventy-five hundredths for shells over fifteen and not over twenty years old.
(d) Six for shells over twenty years old.

In determining the working pressure to be allowed on a second-hand boiler, tank, jacketed kettle, or other apparatus subject to inspection, the factor of safety used shall be:

F S = five and five-tenths for shells not over ten years old.
F S = six for shells over ten years old and not over fifteen years old.

Second-hand boilers, tanks, jacketed kettles, or other apparatus subject to inspection, over fifteen years old, will be allowed a pressure not to exceed ten pounds.

When the tensile strength is not known it shall be taken at 55,000 pounds for steel and 45,000 pounds for wrought iron, 18,000 pounds for cast iron, and 34,000 pounds for copper.

Dished Head.

Convex Heads. The maximum pressure to be allowed on an unstayed dished head with the pressure on the concave side, when it is a segment of a sphere shall be determined by the following formula:

$$P = \frac{(t - \frac{1}{8}) \times 2\ T\ S}{5.5 \times R}$$

P = maximum allowable pressure.
t = thickness of plate.
T S = tensile strength.
R = radius to which head is dished.

Concave Heads. For dished heads with the pressure on the convex side, multiply result of formula above by .6.

Note. To find the radius of a sphere of which the bumped head forms a part, square the radius of head, divide this by the height of bump required; to the result add height of bump, which will equal diameter of sphere, one-half of which will be the required radius.

Braced and Stayed Surfaces.

The maximum allowable working pressure on flat plates supported by stays shall be determined by the following formula:

$$P = C \times \frac{t^2}{P^2}$$

P = maximum allowable working pressure lbs. per sq. in.
t = thickness of plate in sixteenths of an inch.
p = maximum pitch measured between straight lines passing through the centers of the stay bolts in the different rows, which lines may be horizontal, vertical or inclined.
C = 112 for stays screwed through plates not over $\frac{7}{16}$ in. thick with ends riveted over.
C = 120 for stays screwed through plates over $\frac{7}{16}$ in. thick with ends riveted over.
C = 135 for stays screwed through plates and fitted with single nuts outside of plate.
C = 175 for stays fitted with inside and outside nuts and outside washers where the diameter of washer is not less than 0.4p and thickness not less than t.

If flat plates not less than ⅜ in. thick are strengthened with doubling plates securely riveted thereto and having a thickness of not less than two-thirds t, then the value of t in the formula shall be ¾ of the combined thickness of the plates, and the value of C given above may also be increased fifteen per cent.

The ends of stays fitted with nuts shall not be exposed to the direct radiant heat of the fire.

Calculation of Safe Working Pressure.

The usual formula for the calculation of the strength of cylindrical vessels (steam boilers) adopted by the Board of Trade is:

$$P = \frac{t \times T \times s}{r \times f}$$

P = working pressure in pounds per square inch.
t = thickness of plate in inches.
T = tensile strength of plate in pounds per square inch.
s = percentage of strength of joint compared to solid plate.
r = radius of shell in inches.
f = factor of safety (usually 5).

From this formula it may be seen that the larger the diameter of the vessel the less pressure the vessel can withstand for the same thickness of the plate and same tensile strength.

Example. A tubular boiler is 72 inches in diameter and 18 feet long, with double-riveted longitudinal seams of 70% strength, constructed of ⅜ in. steel plates, with a tensile strength of 60,000 pounds per square inch, the factor of safety being 5. What is the safe working pressure?

Solution. By substituting the above figures in the formula we obtain:

$$P = \frac{3 \times 60{,}000 \times 0.70}{8 \times 36 \times 5} = 87.5$$ pounds safe working pressure.

Calculation of Thickness of Plate.

By transposing the above formula the thickness of plate may be calculated:

$$t = \frac{P \times r \times f}{T \times s}$$

Example. What thickness of plate is needed for a boiler that should carry a pressure of 105 pounds? The boiler has double-riveted longitudinal seams of 70% strength, the inside diameter of the shell is 60 inches, the tensile strength of the plate 60,000 pounds. The factor of safety is 5.

Solution. $$t = \frac{105 \times 30 \times 5}{60{,}000 \times 0.70} = 0.375 = \tfrac{3}{8}''.$$

The Hartford Steam Boiler Insurance Co. does not approve of the employment of a plate thicker than one-half inch in the construction of externally fired boilers.

Calculation of Tensile Strength

The above formula may also be transposed so as to permit calculating the tensile strength, thus:

$$T = \frac{P \times r \times f}{t \times s}$$

Calculation of Diameter of Boiler

The diameter of the boiler varies with the efficiency of the joint used in the longitudinal seams as will readily be seen from the examples below. The formula for finding the radius of the boiler, also derived by transposition, is the following:

$$r = \frac{T \times s \times t}{P \times f}$$

Example. A boiler is made of plates $\frac{15}{32}$ inch thick, having a tensile strength of 60,000 pounds, and the joint has 70% the strength of solid plate. The factor of safety is 5, and the boiler should carry 100 pounds pressure. What should be the radius of the boiler?

Solution. The radius $$r = \frac{60{,}000 \times 0.70 \times 15}{100 \times 5 \times 32} =$$ 39.375 or $39\tfrac{3}{8}$ inches, or diameter 78 inches.

If, however, we should use a triple-riveted butt-joint, having 86% efficiency, then the radius of the boiler should be:

$$r = \frac{60{,}000 \times 0.86 \times 15}{100 \times 5 \times 32} = 48.375$$ inches, or the diameter = 96 inches.

Rivets.

Rivets are used for permanently fastening two or more metal plates together. The plates may be either punched or drilled. With punched, there is generally a loss in strength, especially in plates of more than ½ inch thickness, though this may be partly overcome by subsequent annealing. Drilling causes no appreciable loss in strength.

The rivet may be applied in various forms, and either by hand or by machine, the latter being of course the better method. Some of the common forms are the snap or button-head, pan-head, steeple-head, and countersunk.

There seems to be a difference of opinion as to whether steel rivets or wrought iron rivets should be used for riveting steel plates. Recent tests, however, seem to show that there is no disadvantage in using steel rivets, in fact the joint is considered even stronger than when using wrought iron rivets.

Strength of Riveted Joints. There are various styles of riveting, and the strength of joint depends largely on the method used. For ordinary purposes the per cent strengths as compared to the solid plate are taken as follows:

Single-riveted lap-joint—56 per cent.
Double-riveted lap-joint—70 per cent.
Double-riveted butt-joint—80 per cent.
Triple-riveted butt-joint—87 per cent.
Quadruple-riveted butt-joint—93 per cent.

BOILER CONSTRUCTION.

By The Freeman Mfg. Co.

Boiler Shell Plates.

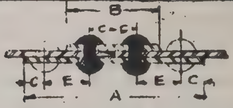
The maximum allowable working pressure on the shell of a boiler or drum shall be determined from the following formula:

$$\frac{T.S \times t \times E}{R \times F.S}$$

T.S = ultimate tensile strength **stamped** on plates.
t = minimum thickness of shell plates.
E = efficiency of longitudinal joint.
R = inside radius of the boiler or shell, using the largest course.
F.S = factor of safety, or the ratio of the ultimate strength of the material to allowable stress.

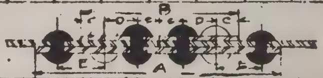
RIVETED JOINTS DESIGNED IN

PLATE AND STRAPS 55000 LBS. T.S.



DOUBLE RIVETED

T	t	RH	EFF	LP.	S.P	A	B	C	E	Drwg No.
1/4	1/4	11/16	828	4	2	8 1/2	4 1/4	1 1/16	2 1/8	
9/32	1/4	11/16	828	4	2	8 1/2	4 1/4	1 1/16	2 1/8	
5/16	9/32	13/16	819	4 1/2	2 1/4	9 7/8	5	1 1/4	2 7/16	
11/32	9/32	13/16	819	4 1/2	2 1/4	9 7/8	5	1 1/4	2 7/16	
3/8	5/16	13/16	819	4 1/2	2 1/4	9 7/8	5	1 1/4	2 7/16	
13/32	5/16	13/16	819	4 1/2	2 1/4	9 7/8	5	1 1/4	2 7/16	
7/16	3/8	15/16	813	5	2 1/2	11 1/4	5 3/4	1 7/16	2 3/4	
15/32	3/8	15/16	813	5	2 1/2	11 1/4	5 3/4	1 7/16	2 3/4	
1/2	7/16	15/16	81.3	5	2 1/2	11 1/4	5 3/4	1 7/16	2 3/4	

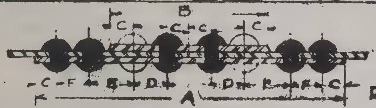


TRIPLE

T	t	RH.	EFF.	LP.	SP	A	B	C	D	E	
1/4	1/4	11/16	875	5 1/2	2 3/4	12	7 3/4	1 1/16	1 3/4	2 1/8	
9/32	1/4	11/16	875	5 1/2	2 3/4	12	7 3/4	1 1/16	1 3/4	2 1/8	
5/16	9/32	13/16	875	6 1/2	3 1/4	13 5/8	8 3/4	1 1/4	1 7/8	2 7/16	
11/32	9/32	13/16	875	6 1/2	3 1/4	13 5/8	8 3/4	1 1/4	1 7/8	2 7/16	
3/8	5/16	13/16	884	7	3 1/2	13 5/8	8 3/4	1 1/4	1 7/8	2 7/16	
13/32	5/16	13/16	884	7	3 1/2	13 5/8	8 3/4	1 1/4	1 7/8	2 7/16	
7/16	3/8	15/16	879	7 3/4	3 7/8	15 1/4	9 3/4	1 7/16	2	2 3/4	
15/32	3/8	15/16	879	7 3/4	3 7/8	15 1/4	9 3/4	1 7/16	2	2 3/4	
1/2	7/16	15/16	88.3	8	4	15 1/4	9 3/4	1 7/16	2	2 3/4	
17/32	7/16	15/16	883	8	4	15 1/4	9 3/4	1 7/16	2	2 3/4	
9/16	7/16	1 1/16	867	8	4	17	11	1 5/8	2 1/4	3	
19/32	1/2	1 1/16	867	8	4	17	11	1 5/8	2 1/4	3	
5/8	1/2	1 1/16	867	8	4	17	11	1 5/8	2 1/4	3	
21/32	1/2	1 1/16	86.7	8	4	17	11	1 5/8	2 1/4	3	
11/16	1/2	1 3/16	85.6	8 1/4	4 1/8	18 1/2	12	1 13/16	2 3/8	3 1/4	
23/32	1/2	1 3/16	856	8 1/4	4 1/8	18 1/2	12	1 13/16	2 3/8	3 1/4	
3/4	1/2	1 3/16	856	8 1/4	4 1/8	18 1/2	12	1 13/16	2 3/8	3 1/4	
25/32	9/16	1 5/16	846	8 1/2	4 1/4	20 1/4	13 1/4	2	2 5/8	3 1/2	
13/16	9/16	1 5/16	846	8 1/2	4 1/4	20 1/4	13 1/4	2	2 5/8	3 1/2	
27/32	9/16	1 5/16	842	8 1/2	4 1/4	20 1/4	13 1/4	2	2 5/8	3 1/2	
7/8	5/8	1 3/16	841	8 3/4	4 3/8	20 1/4	13 1/4	2	2 5/8	3 1/2	
29/32	5/8	1 3/16	836	8 3/4	4 3/8	20 1/4	13 1/4	2	2 5/8	3 1/2	
15/16	11/16	1 5/16	837	9	4 1/2	20 1/4	13 1/4	2	2 5/8	3 1/2	
31/32	11/16	1 5/16	832	9	4 1/2	20 1/4	13 1/4	2	2 5/8	3 1/2	
1	3/4	1 7/16	834	9 1/2	4 3/4	22	14 1/2	2 3/16	2 7/8	3 3/4	

ACCORDANCE WITH A.S.M.E. CODE

RIVETS 44000 LBS. S.S. 88000 LBS. D.S.



QUAD. RIVETED

T	t	RH	EFF	L.P.	M.P.	S.P.	A.	B.	C.	D	E	F	Drwg No
1/4	1/4	11/16	93.8	11	5 1/2	2 3/4	16 1/2	7 3/4	1 1/16	1 3/4	2 1/8	2 1/4	
9/32	1/4	11/16	93.8	11	5 1/2	2 3/4	16 1/2	7 3/4	1 1/16	1 3/4	2 1/8	2 1/4	
5/16	9/32	13/16	93.8	13	6 1/2	3 3/4	18 7/8	8 3/4	1 1/4	1 7/8	2 7/16	2 5/8	
11/32	9/32	13/16	93.8	13	6 1/2	3 1/4	18 7/8	8 3/4	1 1/4	1 7/8	2 7/16	2 5/8	
3/8	5/16	15/16	94.2	14	7	3 1/2	19 1/8	8 3/4	1 1/4	1 7/8	2 7/16	2 3/4	
13/32	15/16	13/16	94.2	14	7	3 1/2	19 1/8	8 3/4	1 1/4	1 7/8	2 7/16	2 3/4	
7/16	3/8	15/16	94.0	15 1/2	7 3/4	3 7/8	21 3/8	9 3/4	1 7/16	2	2 3/4	3 1/16	
15/32	3/8	15/16	94.0	15 1/2	7 3/4	3 7/8	21 3/8	9 3/4	1 7/16	2	2 3/4	3 1/16	
1/2	7/16	15/16	94.1	16	8	4	21 1/2	9 3/4	1 7/16	2	2 3/4	3 1/8	
17/32	7/16	15/16	94.1	16	8	4	21 1/2	9 3/4	1 7/16	2	2 3/4	3 1/8	
9/16	7/16	15/16	94.1	16	8	4	21 1/2	9 3/4	1 7/16	2	2 3/4	3 1/8	
9/16	7/16	1 1/16	93.4	16	8	4	23 5/8	11	1 5/8	2 1/4	3	3 5/16	
19/32	1/2	1 1/16	93.4	16	8	4	23 5/8	11	1 5/8	2 1/4	3	3 5/16	
5/8	1/2	1 1/16	93.4	16	8	4	23 5/8	11	1 5/8	2 1/4	3	3 5/16	
21/32	1/2	1 1/16	93.4	16	8	4	23 5/8	11	1 5/8	2 1/4	3	3 5/16	
11/16	1/2	1 3/16	92.8	16 1/2	8 1/4	4 1/8	25 5/8	12	1 13/16	2 3/8	3 1/4	3 9/16	
23/32	1/2	1 3/16	92.8	16 1/2	8 1/4	4 1/8	25 5/8	12	1 13/16	2 3/8	3 1/4	3 9/16	
3/4	1/2	1 3/16	92.7	16 1/2	8 1/4	4 1/8	25 5/8	12	1 13/16	2 3/8	3 1/4	3 9/16	
25/32	9/16	1 5/16	92.3	17	8 1/2	4 1/4	27 7/8	13 1/4	2	2 5/8	3 1/2	3 13/16	
13/16	9/16	1 5/16	92.3	17	8 1/2	4 1/4	27 7/8	13 1/4	2	2 5/8	3 1/2	3 13/16	
27/32	9/16	1 5/16	91.8	17	8 1/2	4 1/4	27 7/8	13 1/4	2	2 5/8	3 1/2	3 13/16	
7/8	5/8	1 5/16	91.2	17 1/2	8 3/4	4 3/8	28	13 1/4	2	2 5/8	3 1/2	3 7/8	
29/32	5/8	1 5/16	90.5	17 1/2	8 3/4	4 3/8	28	13 1/4	2	2 5/8	3 1/2	3 7/8	
15/16	11/16	1 5/16	90.1	18	9	4 1/2	28 1/8	13 1/4	2	2 5/8	3 1/2	3 15/16	
31/32	11/16	1 5/16	89.5	18	9	4 1/2	28 1/8	13 1/4	2	2 5/8	3 1/2	3 15/16	
1	3/4	1 7/16	90.2	19	9 1/2	4 3/4	30 1/2	14 1/2	2 3/16	2 7/8	3 3/4	4 1/4	
1 1/32	3/4	1 7/16	89.6	19	9 1/2	4 3/4	30 1/2	14 1/2	2 3/16	2 7/8	3 3/4	4 1/4	
1 1/16	3/4	1 7/16	89.0	19	9 1/2	4 3/4	30 1/2	14 1/2	2 3/16	2 7/8	3 3/4	4 1/4	
1 3/32	3/4	1 7/16	88.5	19	9 1/2	4 3/4	30 1/2	14 1/2	2 3/16	2 7/8	3 3/4	4 1/4	
1 1/8	3/4	1 7/16	98.0	19	9 1/2	4 3/4	30 1/2	14 1/2	2 3/16	2 7/8	3 3/4	4 1/4	
1 5/32	3/4	1 7/16	87.5	19	9 1/2	4 3/4	30 1/2	14 1/2	2 3/16	2 7/8	3 3/4	4 1/4	
1 3/16	13/16	1 7/16	87.7	20	10	5	30 5/8	14 1/2	2 3/16	2 7/8	3 3/4	4 5/16	
1 7/32	13/16	1 7/16	87.2	20	10	5	30 5/8	14 1/2	2 3/16	2 7/8	3 3/4	4 5/16	
1 1/4	7/8	1 7/16	86.8	20	10	5	30 5/8	14 1/2	2 3/16	2 7/8	3 3/4	4 5/16	

IMPORTANT – DIMENSION "F" IS ONLY FOR QUAD JOINTS LAYED OUT ACCORDING TO FIG 29 PAGE 108 ASME CODE, WHERE EACH RIVET IN OUTSIDE ROW IS OPPOSITE A RIVET IN SECOND ROW.

The tensile strength of boiler plate usually runs from 55,000 to 65,000 pounds per square inch, and when ordering plate it is necessary to allow the steel mill a range of 10,000 pounds.

The plates are always stamped with the lowest tensile strength specified, which when ordered 55,000 to 65,000 pounds would be 55,000 pounds.

The efficiency of a joint is the ratio which the strength of a joint bears to the strength of the solid plate. In the case of a water tube boiler where tubes enter the shell plate, the percentage of strength between the tube holes is usually less than the efficiency of the riveted joint. The least efficiency must always be used.

The factor of safety is usually 5, and should never be less than this.

Dished Heads.

Convex Heads. The thickness required in an unstayed dished head with the pressure on the concave side when it is a segment of a sphere, shall be calculated by the following formula:

$$t = \frac{5.5 \times P \times L}{2 \times T.S} \text{ plus } \tfrac{1}{8}''$$

t = thickness of plate.
P = working pressure per square inch.
L = radius to which the head is dished in inches.
T.S = tensile strength, pounds per square inch.

The radius of the dish is usually equal to the diameter of the shell to which the head is attached, but if it is less than 80% of the diameter of the shell, L in the formula must not be under 80% of the diameter.

When a dished head has a man hole opening, the thickness of the head should be increased ⅛ of an inch.

Concave Heads. Dished heads with the pressure on the convex side shall have a maximum allowable working pressure equal to 60 per cent of that for heads of the same dimensions with the pressure on the concave side.

Bracing.

When a flat surface is to be braced it is necessary to determine two things: First, the thickness of plate determines the pitch or distance from center to center of braces. It is then necessary to figure the diameter of braces required to carry the load.

To find the maximum allowable working pressure on flat surfaces for various thicknesses of plates, use the following formula:

$$P = C \times \frac{T^2}{p^2}$$

P = maximum allowable working pressure, pounds per square inch.
T = thickness of plate in sixteenths of an inch.
C = 112 for stays screwed through plates not over $\frac{7}{16}''$ thick with ends riveted over.
C = 120 for stays screwed through plates over $\frac{7}{16}''$ thick with ends riveted over.
C = 135 for stays screwed through plates and fitted with single nuts outside of plate.
C = 175 for stays fitted with inside and outside nuts and outside washers where the diameter of washers is not less than T.

If a flat boiler plate not less than ⅜″ thick is strengthened with a doubling plate covering the full area of the stayed surface and securely riveted thereto and having a thickness of not less than ⅔ T, then the value of T in the formula shall be ¾ of the combined thickness of the boiler plate and doubling plate, but not more than one and one-half times the thickness of the boiler plate, and the value of C given above may also be increased 15 per cent.

To find the allowable stress on stay bolts or braces of any kind use the table below.

First find the least area of the brace or staybolt. In the case of staybolts the least area is usually the area at the bottom of the thread. Multiply the area by the constant from the table. This gives the safe load which can be carried by the brace. Divide the safe load by the working pressure and the result will be the number of square inches which the brace will support:

$$\frac{\text{area of brace} \times \text{constant}}{\text{working pressure}} = \text{area brace will support.}$$

Description of Stays	Stresses, Lbs. Per Sq. In. For Lengths Between Supports Not Exceeding 120 Diameters	Stresses, Lbs. Per Sq. In. For Lengths Between Supports Exceeding 120 Diameters
a Unwelded or flexible stays less than twenty diameters long, screwed through plates with ends riveted over	7,500	....
b Hollow steel stays less than 20 diameters long, screwed through plates with ends riveted over	8,000	....
c Unwelded stays and unwelded portions of welded stays, except as specified in lines a and b	9,500	8,500
d Steel through stays exceeding 1½" diameter	10,400	9,000
e Welded portions of stays	6,000	6,000

Modern Method of Factory Heating.

Although every steamfitter ought to know that it is a great mistake to place return pipes underground imbedded in the soil, or still worse, in cinders, and covered in most cases by a concrete floor, I find many instances of that being done. Pipes so placed will rust and must be replaced in a few years, and, besides, if a leak should occur through a cracked fitting or pipe the concrete or wood floor must be torn up and the dirt over the pipe removed. After the leak is fixed the dirt must be filled in, wetted and tamped down solid. This, however, is very seldom done as thoroughly as it should be. The consequence is that there will be settlements and cracks if the floor is made of concrete. It is also next to impossible to know the exact location of a concealed pipe, and therefore, a much wider space has to be opened up than what is really required.

Return pipes, both for gravity and vacuum systems, can always be placed on the wall, where they at all times are accessible, if the construction as employed successfully for several years by many of our best heating engineers is carried out. This construction has been employed in many factory buildings and other buildings where either a wood or concrete floor is placed directly on the soil.

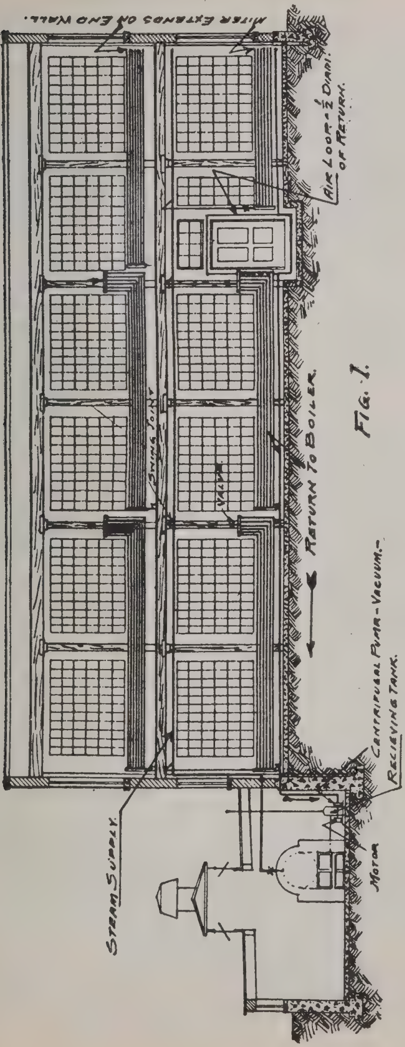

MITER EXTENDS ON END WALL.
AIR LOOP - 1/2 DIAM. OF RETURN.
SWING JOINT
VALVE
RETURN TO BOILER.
CENTRIFUGAL PUMP-VACUUM.-
RELIEVING TANK.
MOTOR
STEAM SUPPLY.

FIG. I.

Figure I shows a longitudinal section of a factory building with boiler room adjoining. In the boiler room is shown a fire box boiler and a centrifugal motor driven vacuum pump with receiving tank. Through practical experience and backed up by many expert heating engineers I can safely advise the use of a centrifugal pump in preference to a reciprocating one. It is more effective and runs much smoother. Connections are made as shown on sketch and given on instruction cards which always are sent with a pump.

The boiler room floor and factory floor can, of course, in a vacuum heating job be placed on the same level, but as it is a good practice to have boiler room in a separate building adjoining the main building, it is advisable to depress the boiler room floor. Care should be taken, however, to ascertain the depth of the sewer in adjoining street and make the floor grade of such a height that pipes for floor drains will have a pitch of not less than ¼″ per foot towards the sewer. The main reason for depressing the boiler room is that by so doing the roof will not need to extend more than 4 feet to 5 feet above the grade and windows can be placed in the adjoining wall of the main building, thereby avoiding a blank, dark wall, as would be the case were the boiler room floor on level with the factory floor.

For radiation in factory buildings I strongly advise built up pipe coils in preference to cast iron wall radiation, as coils are more effective and weigh less. Coils should always have a miter for expansion, or, at the ends of a building, the coil can have a return on the end wall, as noted and showing on sketch. When placing return on the walls we must solve the problem of how to get past one or more door openings, as, of course, the pipe cannot be in the way of free passage. The following construction has been successfully employed in many places and has always given perfect satisfaction and an uninterrupted, noiseless circulation: Build a concrete or plank trench in front of the door opening. It need not be over 8″ to 10″ deep and 10″ to 12″ wide. Trench should extend 8″ to 12″ on each side of the door to allow room for the fittings and also a working space. Drop the return pipe below floor level by constructing a loop as shown on

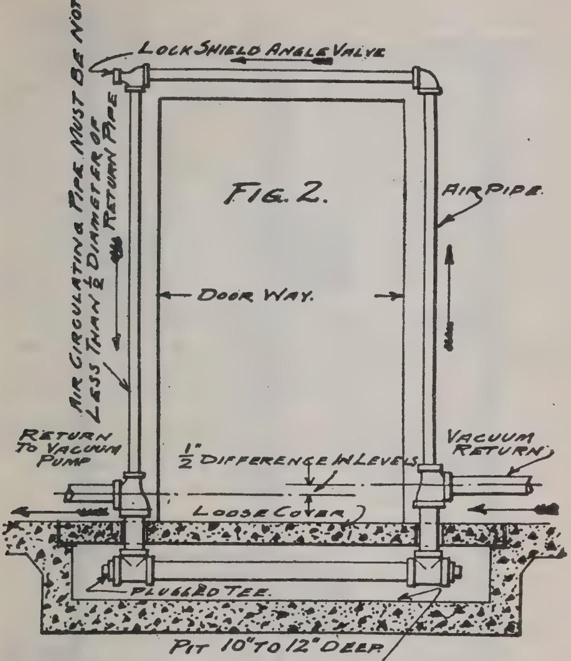
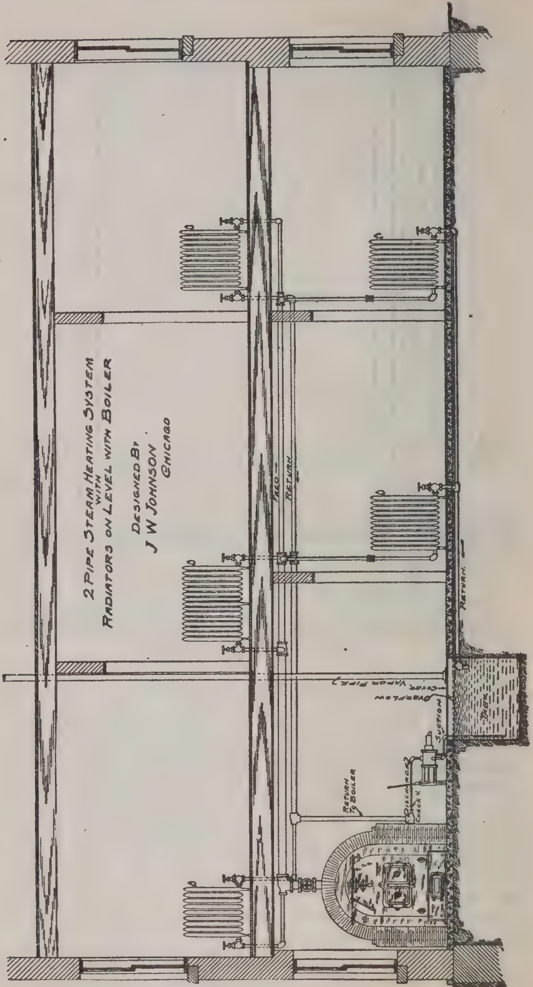


FIG. 2.
LOCK SHIELD ANGLE VALVE
AIR CIRCULATING PIPE MUST BE NOT LESS THAN ½ DIAMETER OF RETURN PIPE
AIR PIPE
DOOR WAY.
RETURN TO VACUUM PUMP
VACUUM RETURN
½" DIFFERENCE IN LEVELS
LOOSE COVER
PLUGGED TEE.
PIT 10" TO 12" DEEP

large size sketch, Figure 2. It is plain to any steamfitter that a drop in the line without any other provision would create a condensation pocket, stop circulation and create a water hammer. By constructing a loop around the door opening we create a perfect free circulation and an absolutely noiseless job. It is not necessary to go into the construction any further, as the large size detail is the best kind of explanation. I will, however, say that the pipes for the air loop should not be less than one-half the diameter of the return pipe. It is advisable to split the coils up into small units, say not over 250 to 300 square feet each. Coils so constructed give a better control of heating the building, as in mild weather, when just a little heat is required, every other coil can be closed off and thereby insure a desired temperature.


2 PIPE STEAM HEATING SYSTEM
WITH
RADIATORS ON LEVEL WITH BOILER
DESIGNED BY
J W JOHNSON
CHICAGO
FLO
RETURN
RETURN
VAPOR PIPE
COVER
OVERFLOW
SUCTION
TANK
RETURN TO BOILER
DISCHARGE
CHECK V

Heating by Steam on Same Level with Boiler.

By this system of heating with steam you can do away with all overhead radiators. Radiators can be placed on the floor or walls on same level with boilers. A more elaborate job can be installed by using a receiving tank, but I am showing the economical way of installing a steam heating plant, and at the same time, doing away with the overhead radiation.

Drawing shows a low pressure system with hand pump. A few strokes of the pump, a few times a day, is all that is required to keep the system free of water.

In a high pressure system a steam pump should be used which can be operated on 20 to 40 pounds of steam pressure.

For the sake of being shown more plainly, the return pipe is shown below the feed pipe. In practice, however, the feed and return pipes will, as usually, be run on about the same level.

Method for Utilizing Heat in Condensation from Central Heating Service, When Condensation is Metered and Wasted.

The accompanying sketch shows an elevation of a graduated valve system of steam heating, designed to utilize the heat in condensation for warming water for domestic use.

The radiators are water type, with feed opening at top, and return at bottom opposite end.

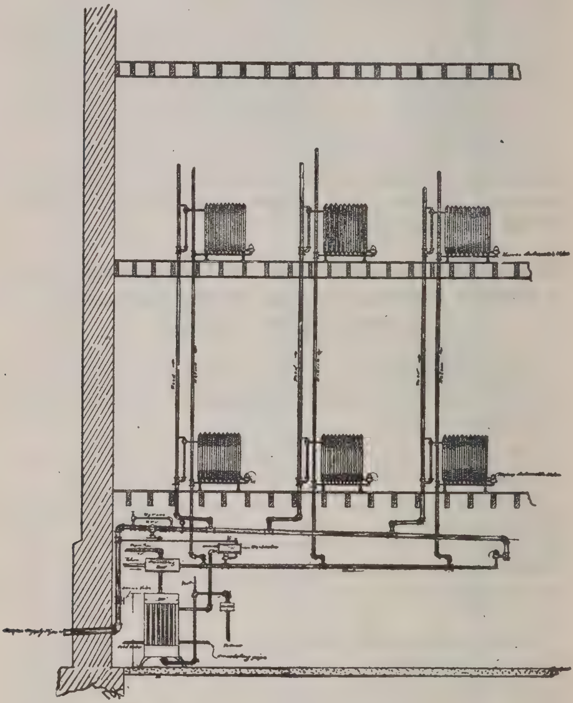
Radiator controlled valves are graduated make, which permits of using as little or much steam needed, according to the requirements of the weather.

The return openings of radiators are fitted with thermostatic traps, that allows the escape of air and water only.

The condensation and air flow through the return pipe to a separating tank in basement when the air is liberated through a vent pipe fitted with swing check valve, the condensation passes through a closed tubular heater, entering at the top of heater and discharging from outlet through loop with vent, to condensation meter.

Cold water supply connects near bottom of heater, and discharges through flow near top of tube chamber, and thence passes through an auxiliary heater that raises the water to the required temperature in case the condensation is not sufficient.

The method has proven very efficient, utilizing heat that is frequently wasted, especially when large quantities of warm water are used.



Fed by Central Heating Plant

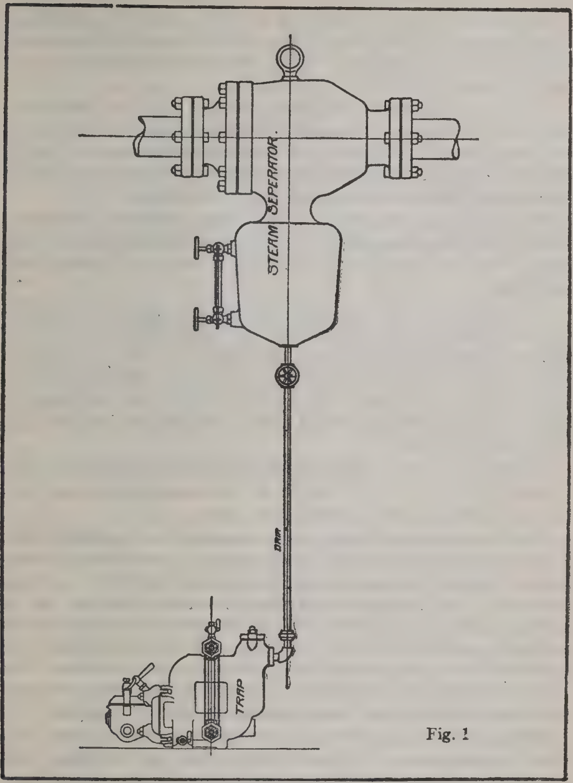


Fig. 1

Steam Traps and Their Duties.

Steam traps are a necessary factor in nearly all power and heating plants, as they effect a great saving by automatically ejecting the condensation without loss of steam, as rapidly as it is accumulated.

All main steam lines should have a trap located at the farthest point from the boiler, thereby insuring dry steam and the highest efficiency for engines, pumps or whatever work the steam has to perform.

All steam separators on main steam lines leading to engines, jacketed cooking kettles, laundry mangles, drying rooms and dry kilns should be trapped, also all heating apparatus where the condensation is not piped direct back to the boiler.

Great care should be taken in the location and position of the trap. It should be placed below the level of the lower opening of whatever apparatus it is to drain, also in a convenient position where it is easily accessible for cleaning out and repairing.

Before attaching the steam trap, blow out thoroughly the steam coil, or apparatus on which the trap is to be used, in order to remove all sediment and rust.

To connect the trap properly, a union and globe valve should be placed on the inlet line and if the trap is discharging above the level of the discharge opening, it is also necessary to have a check valve in the discharge line. No check valve is necessary where the discharge has a free opening and below the level of the trap.

Where several traps discharge into one main discharge line, a check valve is necessary on the discharge line of each individual trap.

One steam trap may be connected to several different apparatus with good results, provided a uniform steam pressure is maintained at all times on the system. It is always advisable when making up a connection of this kind to run the several drips (with a check valve on each line) into as large a header as practicable, and attach the trap to the header, the large header has the effect of equalizing the pressure to a certain degree and produces better results.

When the pressure varies to any extent in the several apparatus or steam coils, the one having the highest pressure will discharge freely and back up into those having a lower pressure, in cases of this kind the best results can only be obtained by attaching separate traps to the ones having unequal pressure.

A very common trouble with steam traps is caused by low places or pockets in the piping system. Water accumulates in these low spots and is forced through into the trap at intervals, causing an uneven discharge. Where the quantity of accumulated water is sufficient and the steam valve in the line is opened suddenly, this water is forced through the pipes at such a high velocity as to cause water hammer, which is very destructive to the whole piping system. Always avoid all low spots or pockets in your piping system.

Fig. (1) shows an Anderson steam trap connected to a horizontal steam separator.

The Anderson is an ideal steam trap, perfect in every detail, accurately built of materials best suited for the purpose. Every part absolutely interchangeable. Complete with water gauge, by-pass, air valve, blow-off valve and sediment strainer. Both the valve and valve seat can be removed without breaking a steam joint or pipe connection. The valve is always locked with at least three inches of water, making the escape of steam impossible. The strainer and sediment chamber prevent sediment or scale getting into the valve. A glass water gauge fitted to the trap makes it possible to ascertain at a glance whether the trap is working properly. These traps will lift water against any back pressure less than the pressure at the trap. Made for high or low pressure or exhaust steam.

Fig. (2) illustrates a means of utilizing the latent heat in the water of condensation from steam heated radiation, where the water is not used for other purposes. This illustration shows an Anderson steam trap which discharges the condensation into an auxiliary heating coil. This coil can be placed either above, below or on a level with the discharge opening of the trap; however, if placed above the trap the steam pressure must be sufficient to elevate the condensation. By this arrangement the latent heat that is stored in the water can be utilized, thereby effecting a great saving. The Anderson trap, being of constant flow, will force the water through these extra hot water coils in a continuous stream and not create water hammer. In installations of this kind a globe valve, check valve and union should be placed between the radiation and steam trap as well as between the coil and trap.

It is obvious that installations of this nature will insure a considerable saving.

Anderson Trap

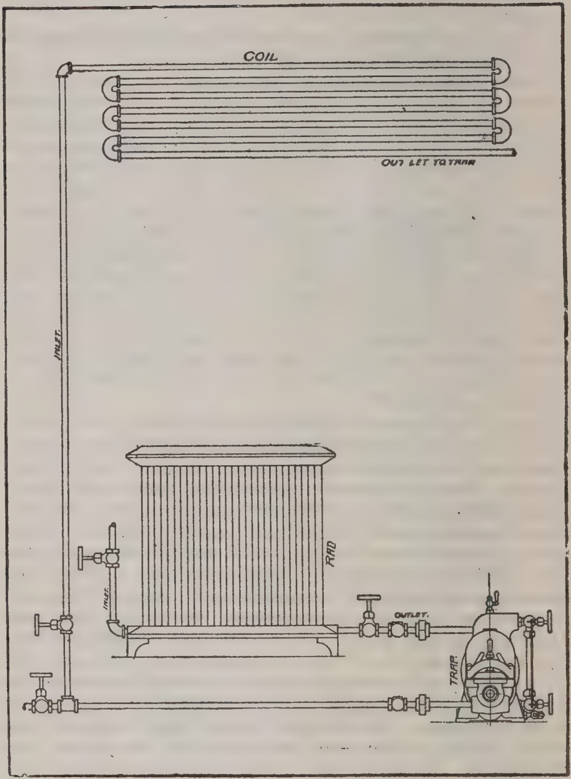
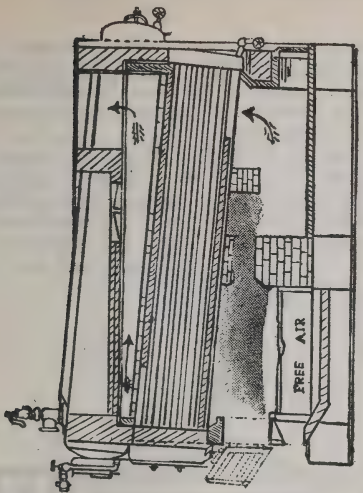
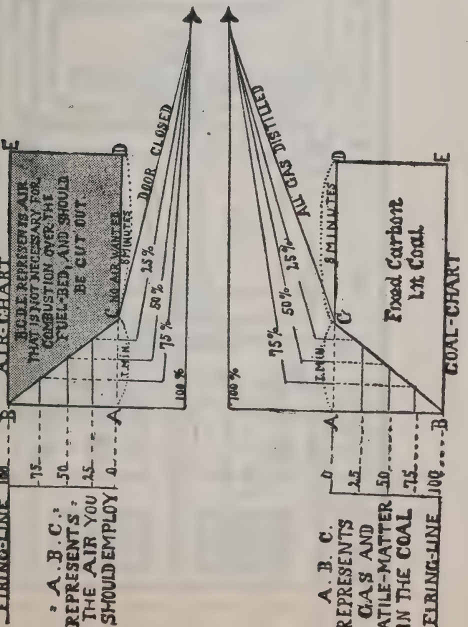

COIL
OUTLET TO TRAP
INLET.
INLET.
RAD
OUTLET.
TRAP

Fig. 2

Automatic Air Furnace, Chicago, Ill.



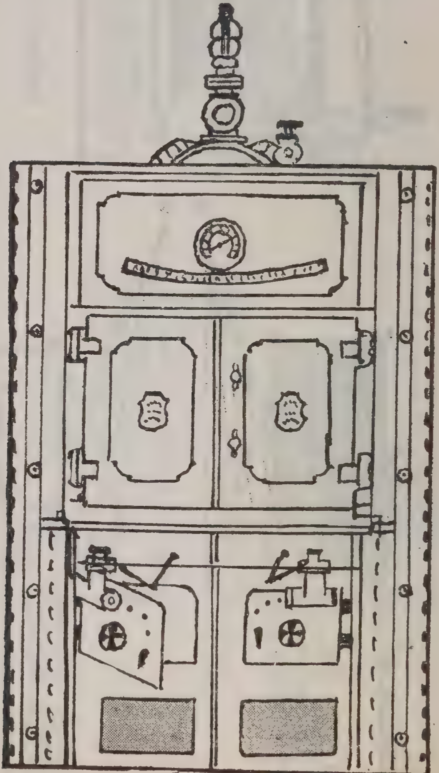
Pat Nov. 24, 1914. Other patent pending



Showing the Automatic Air Furnace

This is what the Automatic Air Furnace is doing the year round at the Great Northern Hotel, Chicago, Ill., with absolutely no smoke or soot, and saves 30 per cent in fuel.

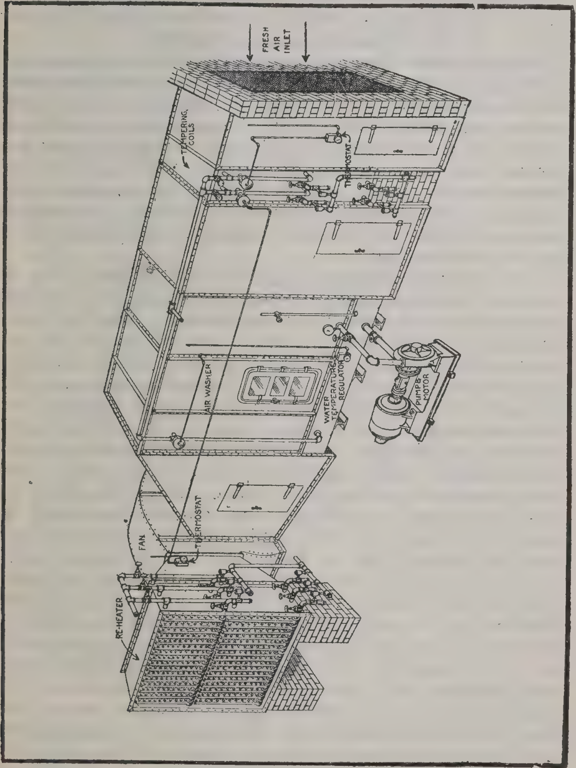
Only one 300 H. P. Boiler in service at a time, furnishing steam for power plant, peak load 1200 amp. 230 volts, 45,000 square feet of heating surface. Heating and pumping all hot and cold water. Live steam for four kitchens, steam vacuum carpet system, Duplex steam pumps and live steam in heating system.



The Only Real Smoke Consumer Ever Invented

Soot and smoke is the bane of most every city. With this furnace installed these obnoxious nuisances will be eliminated and the blessings of a clean city may be enjoyed by all.

This furnace completely consumes all smoke and soot and should be installed in every power plant in America.


FRESH AIR INLET
TEMPERING COILS
THERMOSTAT
AIR WASHER
WATER TEMPERATURE REGULATOR
PUMP & MOTOR
THERMOSTAT
FAN
RE-HEATER

The Webster Standard Air Washer and the Webster Type "A" Air Washer will be discussed here, since they are the types most frequently used in ordinary heating and ventilation. Where either air cleansing or humidity control is the dominant factor in the selection of the apparatus, the Webster Standard Air Washer is recommended. Where air cooling is of importance and air cleansing and humidity control of equal or secondary importance, the Webster Type "A" Air Washer is recommended.

Both include the essential features of a casing, enclosing a spray chamber, spray device and eliminator for the removal of entrained moisture; a water tank extending under the entire apparatus; centrifugal pump for maintaining circulation of spray water between the tank and spray device; and such accessories as a strainer, ball float valve for automatically admitting fresh water, overflow fitting, inspection doors or windows, pressure gauge, mist shields, spray apron and the like.

The Webster Standard Air Washer differs from all others, chiefly in the manner in which the air and spray water are brought into contact. The Webster spray device consists of a brass pipe of ample size extending across the full width of the spray chamber and secured to the roof. This pipe contains a series of apertures on each side, spaced on 6″ centers, for the discharge of the spray water. The water jets impinge on the lips of a curved copper hood-secured to the upper half of the pipe—at a slight angle from the tangential, follow the curve of the hood to its edge, flare out fan-shaped and shoot downward in interlaced sheets of rain and spray crossing the air at a right angle to its flow, and precipitating practically all the dirt from the air directly into the tank.

The water orifices are 7/32″ in diameter, and are absolutely "non-clogging." The strainer covering the end of suction to pump is of rather coarse mesh, so that premature clogging of it is eliminated without endangering the continuous operation of the spray device. This non-clogging feature, as well as the extreme simplicity of the whole, is appreciated by the operating man, since it means little attention. It also eliminates the necessity of mechanical contrivances for automatically flushing the spray device to keep it clean—all of which have been more or less impractical in actual service.

The Webster Eliminator is characteristic and secures many advantages over other types of eliminators. It is built up of horizontal V-shaped, lipped baffles arranged in two separate rows, staggered vertically. The vertical distance between baffles is 4½", which reduces the resistance to the air to a minimum consistent with perfect removal of entrained moisture. Being slightly inclined from the horizontal, the baffles allow the water and any dirt which may have escaped the spray, to drain immediately to a vertical gutter, thence to the tank below. By this arrangement each baffle is handling an equal amount of moisture, and same is immediately removed from further contact with the air current, thereby insuring perfect elimination of entrained moisture.

Mist shields secured to the side angle at the front of the casing break up eddy currents and together with the apron at the front of the tank prevent mist from falling outside.

The length of the Webster Standard Air Washer (3'-10") adapts it to the limited space usually available for apparatus of this character.

The Webster "Type A" Air Washer in its general construction is the same as the Webster Standard. The length is increased to 7'-0", and the method of bringing the water and air into contact is different.

The essential factors necessary to secure highly efficient cooling, are: extremely intimate contact between air and water without handling an excessive water volume; comparatively long contact, and uniform distribution of air and water over the entire spray chamber area. The mist nozzles are placed about one foot from the front of the casing, a header extends the entire width of the apparatus, a few inches above the water line in the tank. Risers are tapped into this at intervals for supplying the mist nozzles, and extend the full height of the casing. The spacing of the risers and nozzles is dependent on the amount of cooling that is desired.

The Webster spiral mist nozzles (patented) used in the Webster "Type A" Air Washer are made of brass. Each consists of a base which screws into the riser, and a casing enclosing a spiral interior casting for giving the water a rotative effect. The casing with enclosed spiral screws into the base. The interior has two spiral water passages of uniformly decreasing cross sectional area. The jets from each spiral leave the same tangentially; the centrifugal action in addition to the interference of the two jets in the orifice causes the water to be atomized into a cone-shaped cloud of mist and fog. The "cones" from the adjacent nozzles interlace so that a uniform distribution of water is secured.

The mist nozzles afford the means of breaking up the spray water so finely that the aggregate surface of the particles into which each gallon of water is divided is very large, thus increasing the rapidity of heat transfer from air to water with the attendant cooling.

Elaborate tests were necessary to determine the cooling obtainable by the "Type A" air washer for different initial air conditions, water temperatures and water volumes. The large number of variables involved makes a rational formula for the calculation of cooling under all conditions practically impossible; with the experimental data resulting from the above mentioned tests, the calculation upon which to proportion air and water volumes for obtaining any desired result, is a very simple matter.

For air cleansing this type is not excelled by any apparatus of the mist nozzle type.

The Webster System of Humidity Control can be applied to either type of apparatus with equal facility. It involves simply the use of ordinary thermostatic devices with which all operating engineers are familiar. The system provides for controlling and maintaining the desired absolute humidity of the air leaving the air washer, and which reheated to the desired room temperature, maintains closely the predetermined relative humidity.

For this purpose a constant predetermined temperature of the air leaving the air washer is maintained by controlling the steam supply to the tempering coil.

The spray water in the air washer tank is warmed and maintained at a practically constant predetermined temperature by the use of a water temperature regulator which controls steam injection through steam and water mixers placed inside the air washer tank. In other words, the desired absolute humidity is obtained by maintaining a practically constant predetermined differential between the temperature of the air leaving the air washer and the temperature of the spray water used.

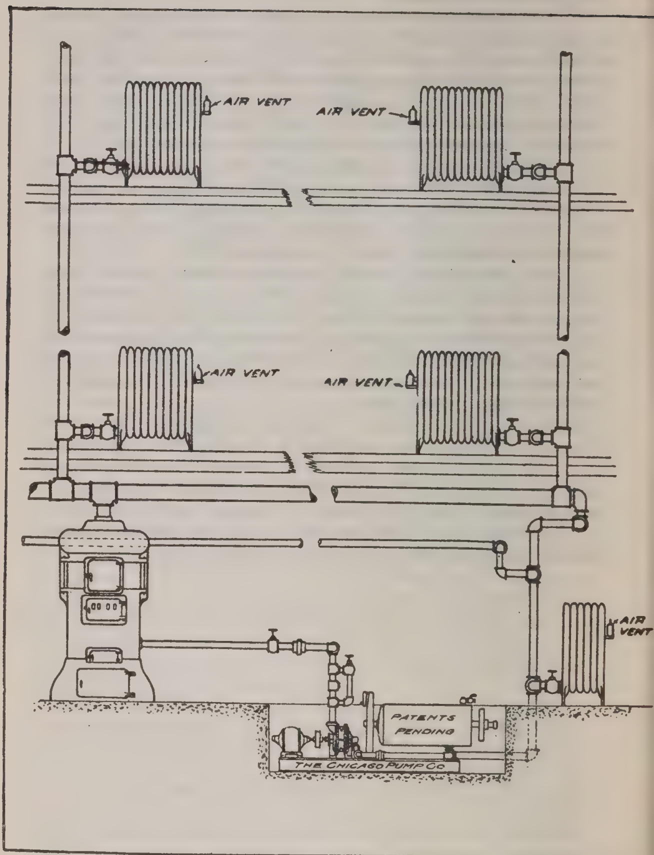
The warming and maintaining of the spray water at a constant predetermined temperature serves the double purpose of enabling the air leaving the primary heater to pass through the air washer and humidifier with but a slight drop in temperature and further enables the air to absorb the water vapor to which the latent heat of evaporation is supplied.

It should further be stated that the air leaving the Webster Air Washer, as usually operated, is never completely saturated, but when arranged for humidity control as above described, would leave the air washer at about 90 per cent saturation.

If we, therefore, desire to obtain an absolute humidity of, say 3.4 grains per cubic foot, corresponding to 50 per cent relative humidity at 65 deg. F., the temperature of the air leaving the air washer should be about 48 deg. F., since air at this temperature and 90 per cent saturation contains 3.4 grains of moisture per cubic foot.

Assuming an extreme outside condition of 0 deg. F., and 50 per cent relative humidity, the absolute humidity is ¼ grain per cubic foot. The difference between this and the desired absolute humidity is the amount of steam which is required per cubic foot of air handled; it then becomes easy to calculate the boiler horse power required for humidification.

Condensation Pumps


AIR VENT
AIR VENT
AIR VENT
AIR VENT
AIR VENT
PATENTS PENDING
THE CHICAGO PUMP Co

Cut illustrating the "Chicago" Condensation Pump and how it can be applied in keeping a heating system clear of condensation water. This condensation pump is far superior over any other make.

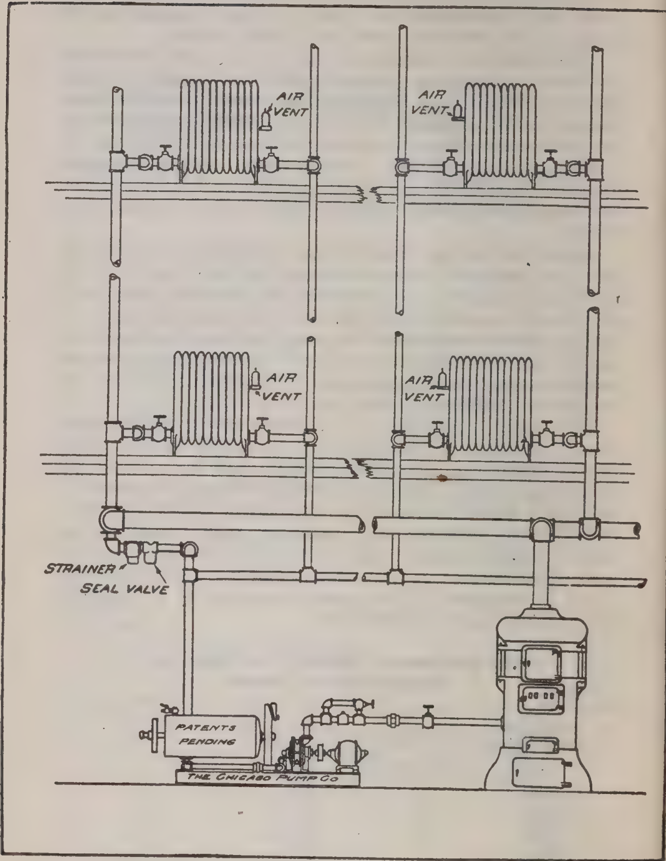
The condensation pump is used where it is desired to keep a heating system clear of water where, through settling of foundations, water pockets have formed in the piping, where the heating pipes are below the water level in boiler, where it is difficult to maintain the proper temperature during winter months; for all these troubles the automatic electric condensation pump affords instant and permanent relief.

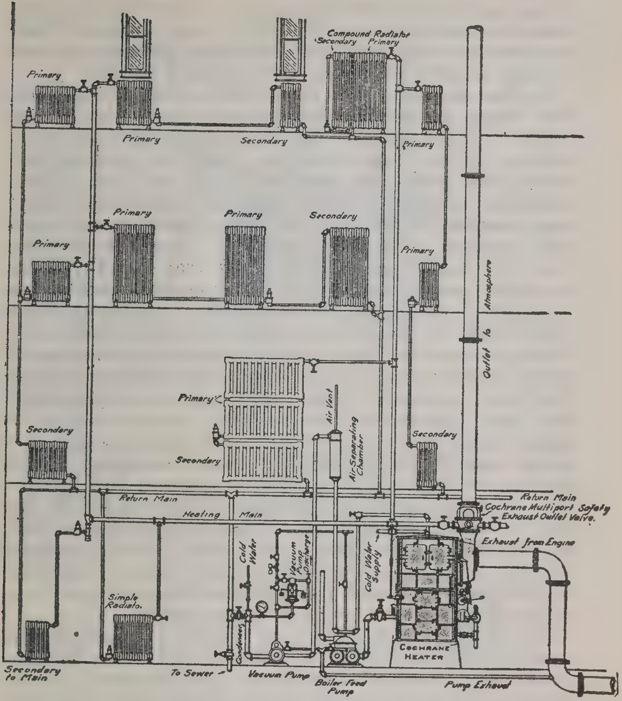
Radiators below water level in boiler may also be kept as clear as if it were above the boiler level; with its use you may avoid placing radiators against ceiling; build a small pit about 2′ deep and about 6′ square, place condensation pump in it and connect return pipe to receiver; this will allow you to place radiators on the floor line and you will avoid the necessity of building a pit for the boiler.

The outfit consists of a turbine pump fitted with outer board ring oiled bearings, electric motor, automatic electric controlling switch and automatic tilt receiving tank. The return water flows into receiving tank until it is nearly full, when it tilts, closing the electric switch and starting pump and motor which pumps water back into boiler when it automatically stops. It operates about 2-3 minutes every 15 to 30 minutes. The cost to operate it is so small it is hardly to be considered.

The following Table gives Sizes on Condensation Pumps

Square Feet Direct Radiation	H. P. of Motor	Approximate Shipping Weight	Boiler Pressures up to
1,000	⅛	300 Lbs.	8 Lbs.
3,000	½	600 "	15 "
6,000	½	650 "	15 "
10,000	¾	700 "	20 "
15,000	2	1,000 "	20 "
20,000	2	1,100 "	20 "
25,000	2	1,200 "	20 "

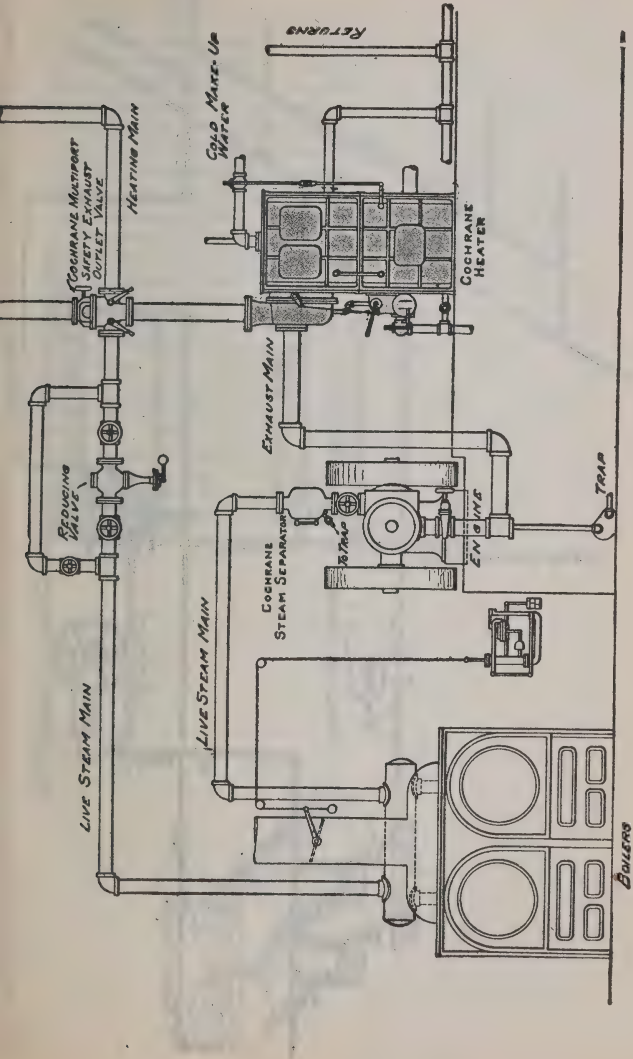

AIR VENT
AIR VENT
AIR VENT
AIR VENT
STRAINER
SEAL VALVE
PATENTS PENDING
THE CHICAGO PUMP CO

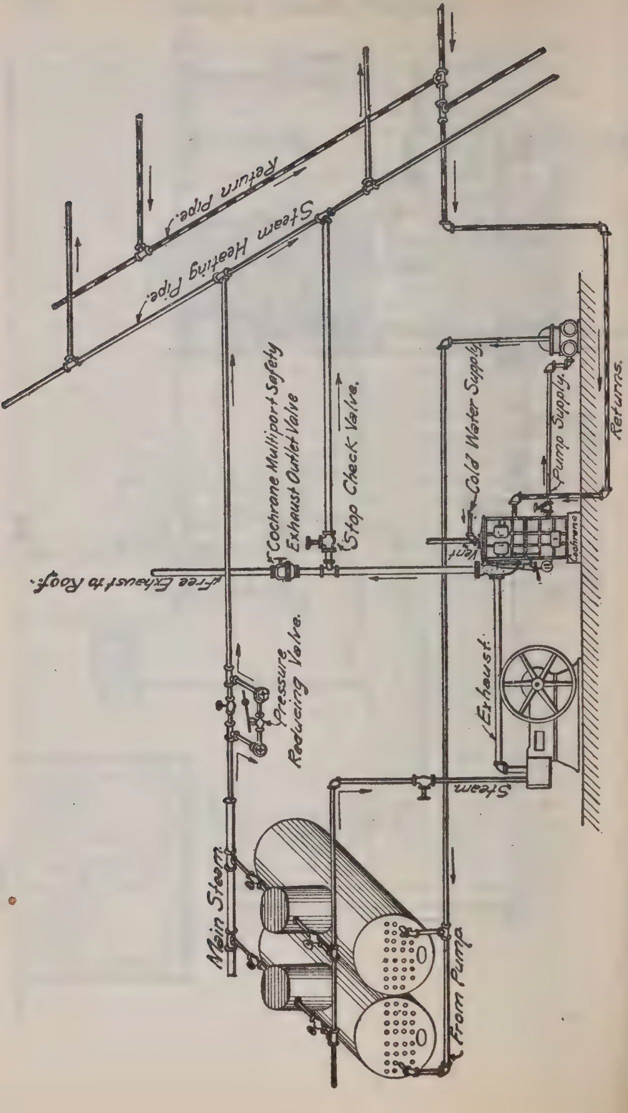

Compound Radiator
Secondary
Primary
Primary
Primary
Secondary
Primary
Primary
Primary
Secondary
Primary
Primary
Outlet to Atmosphere
Primary
Air Vent
Air-Separating Chamber
Secondary
Secondary
Secondary
Return Main
Heating Main
Return Main
Cochrane Multiport Safety Exhaust Outlet Valve.
Exhaust from Engine
Cold Water
Vacuum Pump Discharge
Cold Water Supply
Simple Radiato.
Condenser
Cochrane Heater
Secondary to Main
To Sewer
Vacuum Pump
Boiler Feed Pump
Pump Exhaust

The Cochrane Improved Steam-Stack and Cut-Out Valve Heater and Receiver is an open feed water heater for use in connection with exhaust steam heating systems of both the back pressure and vacuum types, and is distinguished by the extra large oil separator forming a part of it. This separator has sufficient capacity to purify all of the exhaust steam delivered by the engines and pumps, that is, not only the steam consumed in heating the boiler-feed water and reheating the returns in the heater, but also the surplus exhaust steam which passes to the heating or drying system or escapes to the atmosphere. Steam that is to be used in a heating system should always be purified of oil in order that the condensed returns may be suitable for use as boiler feed, and that the heating coils and piping system may not become coated internally with oil and grease.

So that the separator may continue supplying purified steam to the heating system while the heater itself is being opened for cleaning or inspection, a cut-out valve is provided to close the opening between the separator and the body of the heater. Likewise, in order that the trap attached to the heater may continue to drain the separator during such periods, another valve is arranged to close the opening from the heater overflow into the trap. Both valves are operated in conjunction by a combination valve gear, which on the larger sizes is so arranged that the small valve in the trap opens before and closes after the large valve in the separator, whereby unbalanced steam pressure on the large valve is equalized before the latter is moved. These valves, in connection with the large separator, give all the advantages of a heater and receiver plus an independent separator large enough to handle the entire exhaust of the engine and located in a by-pass around the heater. The advantages of the combined arrangement, in the way of simplicity and small space requirements, will be evident by comparing the typical exhaust steam heating systems equipped with this heater, as shown in the drawings, with the usual methods of connecting up installations to do the same work.

Fig. 1, cut 2836, shows a typical exhaust steam heating system installed with a Cochrane Steam-Stack and Cut-Out Valve Heater and Receiver, which dispenses with the return tank, grease extractor, and closed heater with trap to drain same, which would have been required otherwise. The closed heaters ordinarily used, without the protection of an oil separator, soon become coated with oil and grease, greatly reducing their efficiency, while the heating efficiency of the Cochrane heater remains perfect indefinitely, since the heat transmission is immediate from steam to water.


RETURNS
COLD MAKE-UP WATER
COCHRANE MULTIPORT SAFETY EXHAUST OUTLET VALVE
HEATING MAIN
COCHRANE HEATER
EXHAUST MAIN
REDUCING VALVE
TRAP
ENGINE
TO TRAP
COCHRANE STEAM SEPARATOR
LIVE STEAM MAIN
LIVE STEAM MAIN
BOILERS


Return Pipe.
Steam Heating Pipe.
Cochrane Multiport Safety Exhaust Outlet Valve
Stop Check Valve.
Free Exhaust to Roof.
Pressure Reducing Valve.
Cold Water Supply
Pump Supply.
Returns.
Vent
Cochrane
Exhaust.
Steam
Main Steam
From Pump

Illustrates the application of the new heater to the Simonds Compound Vacuum System, in which secondary radiators are employed to utilize the heat remaining in the condensation after it has escaped from the main steam radiators. The use of the secondary radiators results in a lower temperature of the returns which can therefore be handled more easily by the vacuum pump without cold water injection.

Similar economies are shown in the installation of a steam-stack and cut-out valve heater and receiver in connection with the Kieley System. A dozen other exhaust steam heating systems in general use are shown in the "Exhaust Steam Heating Encyclopedia," published by the Harrison Safety Boiler Works, from which we take these illustrations. The money savings from the elimination of the extra separator and trap, and a number of gate valves, elbows, tees, piping and other fittings, amount to from $50 to $500 in each case, or about 25 per cent of the cost of the heater. As compared with a closed heater arrangement, this improved type of heater performs all the functions, and takes the place of closed heater, hot well, expansion tank, boiler feed water skimmer and filter, make-up water regulator, independent oil separator and trap, valves and connections.

Heat Regulating Systems.

Automatic heat regulation is now frequently applied to systems of heating and ventilating, especially in offices of the better class. Its advantages are well known, producing, as it does, the most economical consumption of steam and the highest degree of comfort.

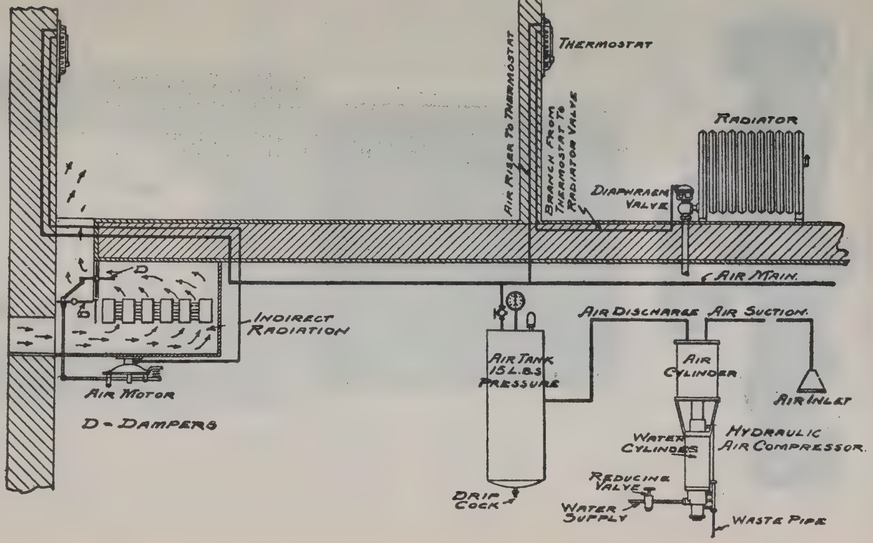
Where the system consists of thermostats connected to valves controlling the heat sources by means of compressed air a diaphragm valve is placed on the radiators.

These valves are furnished by the heat regulating contractor in the commercial sizes and shapes; globe, angle, corner, offset, with and without unions, and have very closely the same dimensions in the body, length of tailpiece, as the commercial valves of all makes, and are provided with standard threads. The system consists of an air compressor which may be of any type, and operated by water, steam or electricity, as may be desired. They are made in different sizes to conform to the different size plants. The air compressor delivers air to the storage tank. From this tank the air is piped to the thermostats located in various parts of the building, as desired. From each one of these thermostats another pipe is run to the valve or to the dampers to be controlled.

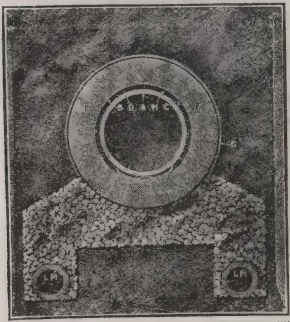
Various sizes and methods of running pipe are employed depending on the kind and character of the building. The piping to the thermostats is called the main pipe, and the pipe from the thermostat to the valves or dampers is called the branch pipe. The main piping is run somewhat similar to steam piping in starting it with large sized pipe, and reducing to smaller size as each thermostat is reached, and, of course, the size of pipe is dependent upon the number of thermostats used in the building. The branch piping is usually small size pipe, seldom more than 1/8" galvanized iron pipe. All pipe used in temperature regulating systems is galvanized iron, with galvanized iron fittings. The piping is entirely concealed in the walls and beneath the floors, excepting where it is run in a regular pipe shaft, and the short connection from the floor to the radiator valves, as illustrated in the sketch.

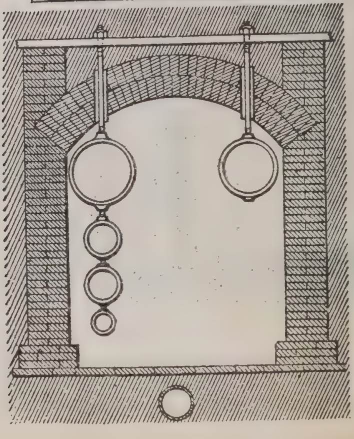
Space does not permit, at this time, to explain the various piping systems in use, but piping of this kind must be run straight and be absolutely without leakage.

JOHNSON SYSTEM OF TEMPERATURE REGULATION.


THERMOSTAT
AIR RISER TO THERMOSTAT
BRANCH FROM THERMOSTAT TO RADIATOR VALVE
RADIATOR
DIAPHRAGM VALVE
AIR MAIN.
D
INDIRECT RADIATION
AIR MOTOR
D - DAMPERS
AIR TANK 15 LBS PRESSURE
DRIP COCK
AIR DISCHARGE
AIR SUCTION.
AIR CYLINDER
AIR INLET
WATER CYLINDER
HYDRAULIC AIR COMPRESSOR.
REDUCING VALVE
WATER SUPPLY
WASTE PIPE

Underground Expansion Joint, Insulation and Tunnel for Underground Work





How steam pipes should be placed in the ground

Blower System and Its Operations

When a problem of heating is presented, wherein it is proposed to use blowers to circulate and distribute warm air, it is necessary to first consider what the building will be used for and the number of occupants.

Such problems can usually be divided into three groups, each subject to several subdivisions, depending upon any number of local conditions.

1. Buildings not requiring ventilation, which are simply to be heated.
2. Buildings in which ventilation is the principal thing to consider, and heat is secondary.
3. Buildings in which heat and ventilation are of equal importance.

Under the first might be given as examples, large, lofty industrial works, wherein the relative space per occupant is very large, the windows of which are loosely fitted and often have numerous broken window panes; also numerous doors, constantly being opened and closed, and not infrequently left open for long periods at a time.

Under the second would come industrial plants wherein noxious gases, smoke and steam are generated. Frequently more heat is given off in the manufacturing process than is necessary to heat the building, but the fresh air introduced has to be warmed in very cold weather to prevent the forming of a fog inside, also to keep the walls and roof from condensing moisture due to the relatively high humidity inside.

Small "moving picture" theaters sometimes come under the second, as the occupants often furnish enough animal heat without any other heat being supplied.

The third covers churches, schools, theaters, auditoriums; etc., where great numbers of people congregate for several hours at a time. This also frequently applies to manufacturing plants wherein shoes, corsets, overalls, clothing, etc., are made. In most of such plants, thousands of employees are huddled together in rooms of limited area and height, thus presenting a condition requiring the most careful engineering to keep the air up to even the poorest standards, without creating objectionable drafts.

The next thing to consider is the prevailing atmospheric conditions outside and what the building will be used for, in order to determine the proper temperature inside to meet the severest weather conditions. Buildings can be divided into two general groups to cover this:

(a) Buildings in which the occupants are at complete rest or the occupation is more or less sedentary.

(b) Buildings in which the work requires constant activity or laborious effort.

Under (a) would be listed all kinds of public buildings, also manufacturing plants wherein the employees are seated simply feeding material to machines that require no muscular exercise beyond moving the hands and arms.

Class (b) would cover all other types, excepting perhaps, factories devoted to the production by special process of something which requires a uniform temperature at all times.

Buildings under Class (a) should be provided with a heating plant to maintain a temperature of about 70 degrees F., in the severest weather.

For buildings in Class (b) are subject to a subdivision into several classes, according to the nature of the work, as for instance:

Foundries, machine shops, furniture factories and paint shops. The temperature usually allowed for these are respectively 50, 60, 70 and 80 degrees in zero weather.

By carefully studying the conditions peculiar to the location of the plant and the use to which it will be put, the most economical proportions can be arrived at, not only for first cost, but also for the cost of operation.

Fuel.

1 pound of coal will evaporate from 7 to 10 pounds of water.

1 pound of dry pine wood will evaporate from 4 to 5 pounds of water.

1 ton of anthracite coal requires a space of 42 cubic feet.

1 ton of bituminous coal requires a space of 44 cubic feet.

1 ton of coke requires a space of 80 cubic feet.

150.35 cubic feet of air are required for the combustion of 1 pound of coal.

The following table shows the resulting inside temperatures when the outside temperature varies from zero with a plant designed for zero weather:

RESULTING INSIDE TEMPERATURE

Class of Buildings	Below Zero Outside				Above Zero Outside		
	Temp. Desired Inside, at zero outside	Temp. Inside, at 10° below outside	Temp. Inside, at 20° below outside	Temp. Inside, at 30° below outside	Temp. Inside, at 10° above zero outside	Temp. Inside, at 20° above zero outside	Temp. Inside, at 30° above zero outside
Foundries	50°	41°	32°	22°	57°	63°	70°
Machine Shops	60°	52°	43°	34°	67°	73°	78°
Furniture Factory	70°	63°	55°	45°	76°	81°	86°
Paint Shops	80°	74°	67°	59°	85°	89°	92°

Outside Temperature	Days per Year	Hours at 10 Hrs. per day	Hours at 24 per day
Zero and Below	4	40	96
Zero to 10 above	6	60	144
10 to 20	11	110	264
20 to 30	34	340	816
30 to 40	61	610	1464
40 to 50	47	470	1128
50 to 60	53	530	1272
Totals	216	2160	5184

The days of prevailing temperatures throughout the year is often a question of importance, to approximate the cost of operation. For latitudes lying between 38 and 46 degrees north, the following table represents a fair average:

The next in order is to determine the heat losses due to the outside exposure, as represented by the glass, wall, floor and roof surfaces of the building. The following table gives the losses in B. T. U.'s per square foot of exposed surface for one degree rise per hour:

Thus for 70° rise for 1000 sq. ft. each, of 12" brick wall, single windows, wood floor on the ground, composition roof over wood and four doors of 60 sq. ft. each, would require heat as follows:

1000 x 70° x 0.33 = 2310 B. T. U. for wall.
1000 x 70° x 1.20 = 8400 B. T. U. for windows.
1000 x 70° x .10 = 700 B. T.U. for floor.
1000 x 70° x .30 = 2100 B. T. U. for roof.
240 x 70° x .42 = 101 B. T. U. for doors.
13611 B. T. U. total.

To this must be added the following:
10% for northerly exposure.
10% if heated in day time only.
30% if heated in day time only and greatly exposed.
50% if heated only at long intervals.

Allowances must also be made for broken windows, open doors to the outside or apartments not heated, etc., which usually is taken care of by an extra air air allowance varying from 10 per cent to 25 per cent, according to the judgment of whoever is laying it out.

A concrete example will best illustrate the further procedure, in the determination of the heat required, the volume of air, etc. For this purpose we will assume that the exposure requires 1,918,400 B. T. U.; that the building contains 1,080,000 cu. ft. of space; that it is to be heated to 65 degrees in zero weather, in the day time only:

Heat for exposure	1,918,400 B. T. U.
Add 10% for heating in day time only	191,840 B. T. U.
	2,110,240 B. T. U.

To care for leakages through windows, doors, etc., an additional amount of heat equal to an air change every two hours will be allowed, raised from 30 degrees to 65 degrees. Thus 1,080,000 cu. ft. ÷ 2 hrs. = 540,000 cu. ft. per hr. × (65°-30°) × .0807 (wt. of 1 cu. ft. air at 30°) × 0.2375 (specific heat of air) = 361,000 B. T. U.

Adding this to the exposure loss as found above, makes a total of 2,471,240 B. T. U. per hour.

It is customary to raise the temperature of the air at the heater to about 130°. In a building of this size the average loss of heat from the ducts by radiation will be roughly 20°, which taken from 130 will leave 110° as the average temperature of the air entering the building. As the temperature to be maintained inside is 65°, then 110°—65° = 45°, the temperature lost to outside exposure.

Therefore, 45° × 0.2375 = 10.7 B. T. U. per pound of air; then 2,471,240 B. T. U. ÷ 10.7 = 231,000 pounds of air per hour, or 3850 pounds per minute.

As the air heated by the coils has to be raised from 0° to 130°, then the total heat to be supplied will be as follows:

130° × 0.2375 × 231,000 lbs. = 7,150,000 B. T. U., or nearly three times the heat represented by the exposure.

If, however, the air is to be recirculated, then the apparatus will only have to be as large as the difference between the lowest allowable inside temperature and the maximum temperature from the heater, which we will say is 32° inside to 130° at the heater. Therefore, the heat required will be 98 × 0.2375 × 231,000 lbs. = 5,375,000 B. T. U., or about 25 per cent less heat.

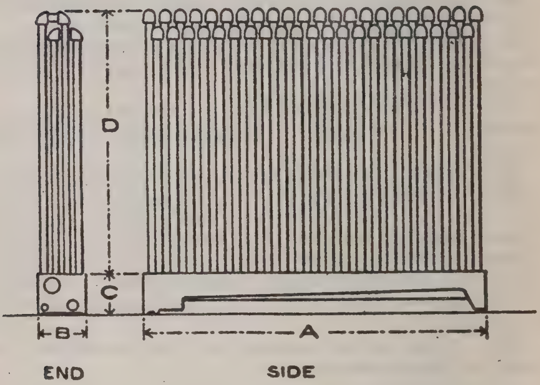
The volume of air required will be as follows, for 3850 lbs. air per minute:

Temp. of air	Cu. ft. air in 1 lb.	Cu. ft. of air per minute
0°	11.58	44,500
32°	12.38	47,600
65°	13.14	50,600
110°	14.35	55,200
130°	14.85	57,200

The velocity of the air over the heating surface should be somewhere between 600 and 1800 ft. per minute. Between 900 and 1200 feet represents average practice. At 1000 ft. velocity, the free area through the heater would have to be somewhere near 50 square feet. Referring to the following table, under No. 40 sections, with pipes 9′-9″ and 10′ high, we find a free area of 49.8 sq. ft. and 567.8 sq. ft. of heating surface per section.

THE "A B C" HEATER

DIMENSIONS OF SECTIONS



No. of Section	A	B	C	D	No. of Section	A	B	C	D	No. of Section	A	B	C	D
12	2′-11⅝″	8¼″	6⅝″	3′-7½″	22	5′-2⅝″	8¼″	7⅛″	5′-4½″	31	7′-3⅝″	8¼″	7⅛″	8′-4½″
12A	2-11⅝	8¼	6⅝	3-4½	22A	5-2⅝	8¼	7⅛	4-10½	31A	7-3⅝	8¼	7⅛	7-7½
12B	2-11⅝	8¼	6⅝	2-10½	22B	5-2⅝	8¼	7⅛	4-4½	31B	7-3⅝	8¼	7⅛	6-10½
15	3-7⅝	8¼	6⅝	4-1½	25	5-10⅝	8¼	7⅛	5-10½	36	8-5⅛	8¼	7⅛	9-4½
15A	3-7⅝	8¼	6⅝	3-10½	25A	5-10⅝	8¼	7⅛	5-4½	36A	8-5⅛	8¼	7⅛	8-4½
15B	3-7⅝	8¼	6⅝	3-7½	25B	5-10⅝	8¼	7⅛	4-10½	36B	8-5⅛	8¼	7⅛	7-4½
18	4-3⅝	8¼	6⅝	4-10½	28	6-7⅛	8¼	7⅛	6-7½	40	9-4⅛	8¼	8⅛	11-1½
18A	4-3⅝	8¼	6⅝	4-4½	28A	6-7⅛	8¼	7⅛	6-1½	40A	9-4⅛	8¼	8⅛	10-1½
18B	4-3⅝	8¼	6⅝	3-10½	28B	6-7⅛	8¼	7⅛	5-7½	40B	9-4⅛	8¼	8⅛	9-1½

The average volume through the heater when recirculating will be $\frac{47,600 \times 57,200}{2} = 52,400 \div 49.8$ sq. ft. = 1050′ velocity per minute.

By means of the following table, the temperature rise for any number of four row sections in depth can be determined for any velocity.

Thus we want 130° with entering air at 32°, or a rise of 98°. If the steam pressure is 5 pounds, with a temperature of 227° and the entering air 32°, the difference is 195°; dividing this by 98° equals 1.99, which is the proper factor for 1050′ velocity, which by interpolation from the table we find is about four sections with four rows of pipe per section.

HEATING APPARATUS

TO DETERMINE TEMPERATURE RISE FOR ANY STEAM PRESSURE OR INITIAL TEMP

$$R = \frac{(T-t)}{K},$$

T = TEMP STEAM
t = " INCOMING AIR
R = RISE
K = CONSTANT AS FOLLOWS

K - IS AS FOLLOWS FOR ANY PRESS AND INITIAL TEMP.

Nº OF SECTIONS DEEP	300′ VEL.	450′ VEL.	600′ VEL.	900′ VEL.	1200′ VEL.	1500′ VEL.	1800′ VEL.	2100′ VEL.	2400′ VEL.	3000′ VEL.
1	3.9	4.46	4.91	5.57	6.2	6.66	7.09	7.45	7.80	8.4
2	2.19	2.5	2.76	3.13	3.48	3.75	3.97	4.19	4.38	4.71
3	1.615	1.85	2.04	2.30	2.56	2.75	2.92	3.08	3.22	3.48
4	1.333	1.525	1.68	1.91	2.12	2.28	2.42	2.55	2.67	2.87
5	1.21	1.35	1.46	1.66	1.85	1.99	2.11	2.22	2.32	2.50
6	1.142	1.23	1.32	1.49	1.66	1.785	1.895	2.00	2.085	2.26
7	1.11	1.065	1.24	1.385	1.54	1.66	1.76	1.85	1.94	2.08
8	1.088	1.150	1.19	1.310	1.44	1.55	1.65	1.73	1.81	1.95
9	1.072	1.113	1.152	1.26	1.36	1.46	1.55	1.635	1.71	1.85
10	1.06	1.10	1.130	1.220	1.305	1.40	1.49	1.57	1.64	1.766

DIVIDE (T-t) BY ABOVE CONSTANT = TEMPERATURE RISE FOR ANY STEAM PRESSURE AND ANY INITIAL TEMP.
IF "t" IS ABOVE ZERO ADD TO "R" FOR FINAL TEMPERATURE
IF "t" IS BELOW ZERO DEDUCT FROM "R" FOR FINAL TEMPERATURE

As each of the sections has 567.8 sq. ft. of heating surface, so the entire heater will have 2271.2 sq. ft., or about 6600 lineal feet of one-inch pipe.

The amount of steam required can be determined as follows:

Total heat in steam at 5 lbs. is..........1156 B. T. U.
Heat in condensation at 212 deg........ 180 B. T. U.
Latent heat given off is................ 976 B. T. U.

5,375,000 ÷ 976 = 5500 lbs. of steam per hour maximum.

As there are 33,305 B. T. U. per boiler H. P. then dividing same by 976 = 34.1 lbs. water per H. P.; then 5500 ÷ 34.1 = 161 H. P. capacity.

If coal contains 13,000 B. T. U. per lb. and boiler evaporates at 70 per cent efficiency, then from each pound of coal 9100 B. T. U. goes to evaporation, which divided by 976 gives 9 1/3 lbs. of steam per pound of coal.

34.1 ÷ 9.33 = 3.45 lbs. of coal per H. P. hour × 161 H. P. = 556 lbs. of coal per hour.

This would amount to about 300 tons per year for period of average heating, at 10 hours per day.

If there is enough exhaust steam to supply the required amount, then no fuel will have to be burned for heating.

The steam main can be determined in several ways. From a steam table find the volume at 5 lbs. pressure, which is 20.08 cu. ft. per lb. × 5500 lbs. = 110,440 cu. ft. per hour or 1840 cu. ft. per minute.

6000 ft. velocity is a reasonable figure to allow, hence $\frac{1840 \times 144}{6000} = 44.2$ sq. in. area, or 7½ in. diameter of main. If the main is very long, then to prevent loss of pressure, it had better be made 8 inches diameter, but if short, 7 inches will be ample.

The return main is usually 6/10 of the area of the steam main which would make it necessary to use a 6″ return for the condensation. With a vacuum system attached, slightly smaller returns can be used. Some even advocate one size smaller steam mains when a vacuum system is attached, but this practice is questionable, as it takes just so much power to move a given volume of steam, whether it is done by pressure or vacuum.

The next thing is the selection of a fan suitable for the work.

It is desirable to keep the air pressure as low as possible, so as not to waste power in driving the fan. The heater will require from 0.25 inches to 0.50 inches in most cases, depending upon the number of sections deep and the velocity. In this case it will be about 0.3 inches.

The distributing ducts should be so designed as not to exceed 0.75 inch loss of pressure. This will make about one inch static pressure, which represents approximately 2/3 of the total pressure, making the total pressure about 1.5 inches or 0.87 ounces.

As we want about 51,000 C. F. M. at 70 degs. temp., then a 160″ fan will be required at 242 R. P. M., requiring about 40 H. P. to drive.

A No. 13 Sirocco fan at 170 R. P. M. will also do the work, requiring 22.05 H. P. The speeds and powers in both of above cases are found as follows:

The volume is directly proportional to the speed, and the power is directly proportional to the cube of the speed; hence if the volume desired is between two sizes or two pressures, in the table the required speed and power can be determined by proportion.

The pressure will be as the square of the speed.

Having now determined the size of the apparatus, the method of distributing the air to properly heat and ventilate the building must be considered.

"A B C" STEEL PLATE FANS

Speeds, Capacities and Horse-Powers at Varying Pressures

Fan No.	Dia m Wheel	Static Press.	½"	1"	1½"	2"	2½	3"	3½"	4"
50	30	C.F.M.	3840	5425	6640	7650	8595	9400	10110	10810
		R.P.M.	471	665	816	945	1060	1150	1250	1330
		B.H.P.	.88	2.48	4.55	7.00	9.81	12.85	16.20	19.75
60	36	C.F.M.	5475	7740	9460	10900	12250	13400	14410	15420
		R.P.M.	393	555	681	786	880	961	1040	1110
		B,H.P.	1.25	3.53	6.49	9.94	14.00	18.35	23.10	28.10
70	42	C.F.M.	7100	10020	12280	14150	15900	17400	18700	20010
		R.P.M.	336	475	583	675	755	825	890	950
		B.H.P.	1.62	4.58	8.35	12.93	18.19	23.80	29.90	36.60
80	48	C.F.M.	8640	12200	14950	17200	19350	21150	22800	24350
		R.P.M.	294	416	511	590	660	722	780	832
		B.H.P.	1.97	5.57	10.20	15.71	22.10	28.90	36.50	44.50
90	54	C.F.M.	11000	15540	19000	21900	24600	26950	29000	31000
		R.P.M.	262	370	454	525	587	641	693	740
		B.H.P.	2.52	7.08	13.00	20.00	28.10	36.85	46.40	56.50
100	60	C.F.M.	14050	19850	24300	28000	31450	34400	37000	39600
		R.P.M.	236	333	409	473	529	578	625	665
		B.H P.	3.21	9.05	16.65	25.60	35.95	47.10	59.10	72.30
110	66	C.F.M.	16600	23500	28800	33100	37200	40700	43800	46900
		R.P.M.	214	303	371	430	480	525	568	605
		B.H.P.	3.80	10.75	19.70	30.25	42.50	55.60	70.00	85.60
120	72	C.F.M.	20300	28700	35100	40500	45500	49700	53500	57300
		R.P.M.	196	278	340	394	440	481	520	555
		B.H.P.	4.64	13.10	24.00	37.00	52.00	68.00	85.50	104.50
140	84	C.F.M.	27400	38700	47400	54500	61300	67000	72200	77250
		R.P.M.	168	238	292	337	378	413	445	475
		B.H.P.	6.25	17.75	32.40	49.80	70.00	91.70	115.20	140.9
160	96	C.F.M.	34500	48900	59800	68900	77300	84500	91000	97500
		R.P.M.	147	208	256	296	331	362	390	416
		B.H.P.	7.88	22.30	41.00	62.90	88.40	115.5	145.4	178.0
180	108	C.F.M.	42600	60300	73800	85000	95500	104300	112500	120000
		R.P.M.	131	185	227	262	293	320	346	369
		B.H.P.	9.75	27.55	50.50	77.60	109.0	143.0	180.0	219.0
200	120	C.F.M.	51600	73000	89400	103000	115700	126500	136100	145800
		R.P.M.	118	166	204	236	264	289	312	332
		B.H.P.	11.8	33.30	61.20	93.50	132.1	173.0	217.50	266.0
220	132	C.F.M.	61400	86800	106000	122200	137400	150200	162000	173000
		R.P.M.	107	151	185	214	240	262	283	302
		B.H.P.	14.0	39.60	72.50	111.50	157.0	206.0	259.0	316.0
240	144	C.F.M.	72000	101800	124500	143500	161000	176000	189500	203000
		R.P.M.	98	139	170	197	220	241	260	377
		B.H.P.	16.5	46.50	85.00	131.00	184.0	241.0	303.0	370.5

NOTE—Any of the above fans, when running at the speed and pressure indicated, will deliver the volume of air and require no more power than given in the table

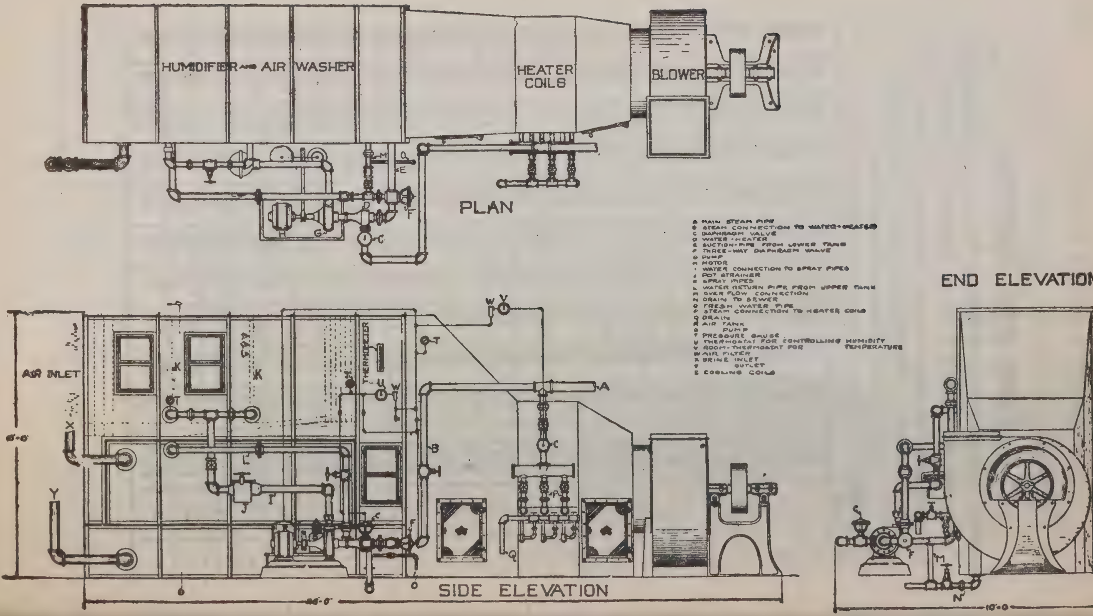
Allowances must be made for the inefficiency of the motive power and for transmission losses between motive power and the fan.

Fans and Blowers

Speeds, Capacities and Horse Powers of Single Inlet, Standard Width Fans at Various Pressures

Figures Given Represent Dynamic Pressures in Ounces per Square Inch. For Static Pressure Deduct 28.8%. For Velocity Pressure Deduct 71.2%.

No. of Fan	Diameter of Wheel		¼ Oz.	½ Oz.	¾ Oz.	1 Oz.	1¼ Oz.	1½ Oz.	1¾ Oz.	2 Oz.	2½ Oz.	3 Oz.
00	3	CU. FT.	38	55	67	77	87	95	102	110	122	135
		R. P. M.	2290	3230	3960	4580	5120	5600	6050	6460	7232	7920
		B. H. P.	.006	.013	.024	.037	.051	.068	.085	.105	.145	.190
0	4½	CU. FT.	87	125	152	175	197	215	232	250	277	305
		R. P. M.	1524	2152	2640	3048	3400	3732	4040	4304	4816	5280
		B. H. P.	.011	.030	.053	.084	.116	.153	.193	.238	.330	.433
1	6	CU. FT.	165	230	270	310	350	380	410	440	490	540
		R. P. M.	1145	1615	1980	2290	2560	2800	3025	3230	3616	3960
		B. H. P.	.0185	.052	.095	.147	.205	.270	.34	.42	.58	.76
1¼	7½	CU. FT.	242	344	422	485	548	594	640	688	768	844
		R. P. M.	915	1290	1585	1830	2050	2240	2420	2580	2890	3170
		B. H. P.	.029	.082	.149	.230	.320	.422	.532	.656	.910	1.19
1½	9	CU. FT.	350	500	610	700	790	860	930	1000	1110	1220
		R. P. M.	762	1076	1320	1524	1700	1866	2020	2152	2408	2640
		B. H. P.	.042	.115	.216	.333	.463	.610	.77	.95	1.32	1.73
2	12	CU. FT.	625	880	1080	1250	1400	1530	1650	1770	1970	2170
		R. P. M.	572	808	990	1145	1280	1400	1512	1615	1808	1980
		B. H. P.	.074	.208	.381	.588	.82	1.08	1.36	1.66	2.32	3.03
2½	15	CU. FT.	975	1380	1690	1950	2180	2400	2590	2760	3090	3390
		R. P. M.	456	645	790	912	1020	1120	1210	1290	1444	1580
		B. H. P.	.115	.326	.600	.923	1.29	1.69	2.14	2.61	3.65	4.8
3	18	CU. FT.	1410	1990	2440	2820	3160	3450	3720	3980	4450	4880
		R. P. M.	381	538	660	762	850	933	1010	1076	1204	1320
		B. H. P.	.167	.470	.862	1.33	1.85	2.43	3.07	3.75	5.25	6.9
3½	21	CU. FT.	1925	2710	3310	3850	4290	4700	5070	5420	6060	6620
		R. P. M.	326	462	565	652	730	800	854	924	1032	1130
		B. H. P.	.227	.640	1.17	1.81	2.53	3.33	4.18	5.11	7.15	9.4
4	24	CU. FT.	2500	3540	4340	5000	5600	6120	6620	7080	7900	8650
		R. P. M.	286	404	495	572	640	700	756	807	904	990
		B. H. P.	.296	.832	1.53	2.35	3.28	4.32	5.44	6.64	9.3	12.2
4½	27	CU. FT.	3175	4490	5500	6350	7100	7780	8400	8980	10050	11000
		R. P. M.	254	359	440	508	568	622	672	718	804	880
		B. H. P.	.373	1.05	1.94	2.98	4.16	5.48	6.90	8.44	11.8	15.5
5	30	CU. FT.	3910	5530	6770	7830	8750	9600	10350	11050	12350	13550
		R. P. M.	228	322	395	456	510	560	604	645	722	790
		B. H. P.	.460	1.30	2.40	3.68	5.15	6.75	8.53	10.4	14.5	19.1
6	36	CU. FT.	5650	7950	9750	11300	12640	13800	14900	15900	17800	19500
		R. P. M.	190	269	330	381	425	466	504	538	602	660
		B. H. P.	.665	1.87	3.44	5.30	7.40	9.72	12.25	15.0	20.9	27.5
7	42	CU. FT.	7700	10850	13300	15400	17170	18800	20300	21700	24250	26600
		R. P. M.	163	231	283	326	365	400	432	462	516	566
		B. H. P.	.903	2.55	4.69	7.24	10.1	13.3	16.7	20.4	28.5	37.5
8	48	CU. FT.	10000	14150	17350	20000	22400	24500	26500	28300	31600	34700
		R. P. M.	143	202	248	286	320	350	378	403	452	495
		B. H. P.	1.18	3.32	6.10	9.40	13.1	17.2	21.75	26.6	37.1	48.8
9	54	CU. FT.	12700	17950	22000	25400	28400	31100	33600	35900	40200	44000
		R. P. M.	127	179	220	254	284	311	336	359	402	440
		B. H. P.	1.49	4.20	7.75	11.9	16.6	21.9	27.6	33.7	47.1	62
10	60	CU. FT.	15650	22100	27100	31300	35000	38400	41400	44200	49400	54200
		R. P. M.	114	161	198	228	255	280	302	322	361	396
		B. H. P.	1.84	5.20	9.58	14.7	20.6	27.0	34.1	41.6	58.2	76.5
11	66	CU. FT.	18950	26800	32850	37900	42300	46400	50100	53600	60000	65700
		R. P. M.	104	147	180	208	232	254	275	294	329	360
		B. H. P.	2.23	6.30	11.6	17.8	24.9	32.7	41.2	50.4	70.4	92.6
12	72	CU. FT.	22600	31800	39000	45200	50600	55200	59600	63600	71200	78000
		R. P. M.	95	134	165	190	212	233	252	269	301	330
		B. H. P.	2.66	7.48	13.7	21.2	29.6	38.9	49.0	58.8	83.6	110
13	78	CU. FT.	26400	37350	45800	52800	59100	64700	70000	74700	83500	91600
		R. P. M.	88	124	153	176	197	215	233	248	278	305
		B. H. P.	3.10	8.77	16.1	24.8	34.7	45.6	57.5	70.2	98	129
14	84	CU. FT.	30800	43400	53200	61600	68700	75200	81200	86800	97100	106400
		R. P. M.	81	115	142	163	182	200	216	231	256	283
		B. H. P.	3.61	10.2	18.7	28.9	40.4	53.0	66.8	81.7	114	150
15	90	CU. FT.	35350	49800	61000	70500	78800	86400	93300	99800	111800	122000
		R. P. M.	76	107	132	152	170	186	201	214	241	264
		B. H. P.	4.14	11.7	21.5	33.1	46.2	60.7	76.7	93.8	131	172


HUMIDIFIER AND AIR WASHER
HEATER COILS
BLOWER
PLAN
END ELEVATION
SIDE ELEVATION
AIR INLET
THERMOMETER
A MAIN STEAM PIPE
B STEAM CONNECTION TO WATER-HEATER
C DIAPHRAGM VALVE
D WATER-HEATER
E SUCTION-PIPE FROM LOWER TANK
F THREE-WAY DIAPHRAGM VALVE
G PUMP
H MOTOR
I WATER CONNECTION TO SPRAY PIPES
J POT STRAINER
K SPRAY PIPES
L WATER RETURN PIPE FROM UPPER TANK
M OVER FLOW CONNECTION
N DRAIN TO SEWER
O FRESH WATER PIPE
P STEAM CONNECTION TO HEATER COILS
Q DRAIN
R AIR TANK
S PUMP
T PRESSURE GAUGE
U THERMOSTAT FOR CONTROLLING HUMIDITY
V ROOM-THERMOSTAT FOR TEMPERATURE
W AIR FILTER
X BRINE INLET
Y OUTLET
Z COOLING COILS
6'-0"
10'-0"

The character of the building and the purpose for which it is built must be carefully studied. What answers for one type of building is totally unsuited to another of a different type. Again what serves nicely in a building of a certain type, in which a particular class of work is done, often proves anything but satisfactory in a building of the same type in which a different kind of work is done; for example, compare a machine shop with a paper mill.

Both are similar in size, shape and exposure. In the machine shop no steam or moisture is emitted to condense on the walls and roof, whereas tons of water is thrown off into the air in a paper mill every day which must be taken care of by the amount and distribution of air circulated.

Then, aside from the work done inside the building, the character of design and construction influence the distribution of heat and air.

The tendency to build lofty industrial buildings with steel frames, narrow pilasters and shallow panels of brick or concrete beneath the windows, which fill most of the space between the pilasters, results in enormous surface exposures that conduct away heat very rapidly, thus producing an unbearable downward circulation of cold air near the outside walls, which has to be neutralized or counteracted by the distributing system.

The modern shop has a trussed roof, the bottom chords of which are often 30 to 50 feet above the floor. The ducts have to rest on these trusses and it is impossible to drive air from them down to the floor in a way that will produce satisfactory results. This method has been tried often enough, but there still remain others who must be convinced of its impracticability by trying it themselves. The only way to obtain an even distribution of heat, is to discharge heated air at such points as it is most needed and where the effect will be most appreciated.

To distribute the heat evenly necessitates running the ducts to all cold spots; it is needed the most in the lower strata near the floor, not up among the roof trusses; the greatest benefit is derived from the system by diffusing the warm air close to the floor, keeping the lower strata in circulation and thereby warming it by mixing with it the warm air discharged from the ducts.

The best way to bring this about is to extend the branch ducts from the main trunk line over to the walls or to posts not more than 20 feet away from the outside walls; then down toward the floor, ending four or five feet from the floor. The air should discharge directly toward the floor or at only a slight angle from perpendicular. This method will be found most effective in machine shops, foundries and other lofty structures.

In paper mills, rubber works, dye houses and other plants for which the building is of the same type as those just noted, it is necessary to blow some hot air out towards the roof as well as down towards the floor, in order to take care of the condensation which would otherwise collect on the under side of the roof. Even then, in very cold climates, it is sometimes necessary to put in a false ceiling to overcome this annoyance, particularly if the roof is built of a material which is a good conductor of heat.

For buildings which are several stories in height, each story being from 10 to 16 feet high, the treatment should be different. With them, it is possible, and sometimes advisable, to introduce the air near the ceiling, blowing downward at an angle of 30 to 45 degrees from horizontal.

Frequently buildings of this character are quite effectively heated from one or two galvanized iron standpipes run up through the middle of the building with outlets into each story. This method is practical in buildings not over 60 feet wide; if the building is not over 100 feet long, one riser will be sufficient.

For cotton, woolen or silk mills it has become almost the universal practice to build vertical warm air flues on the outside face of the pilasters, on both sides of the building. These flues usually have a two-inch air space built into the brick work to insulate them. The air is admitted to each story about eight feet above the floor. Deflecting "mill dampers" regulate the volume of air discharged through each opening. The various flues can be supplied at their base from a main duct built either of masonry or galvanized iron.

For manufacturing plants it is customary to make the trunk line ducts of such an area as will convey the required volume of air at a velocity varying from 1500 to 2400 feet per minute. In high buildings used for heavy and coarse work, where most of the employees stand or move about considerably, the velocity can be much higher than in shops divided into several stories, or those in which the work is more or less sedentary, like the manufacture of shirts, gloves, etc., where the employees sit all day, simply feeding the material into machines.

Air currents or drafts are of not material moment in the former shops, while in the latter they will produce great discomfort, if not sickness. Therefore, the latter class should have the main ducts of sufficient area to keep the velocity down to 1200 to 1800 feet per minute and the branches should be proportioned to a velocity of 600 to 1200 feet.

Another advantage the blower system possesses, infrequently brought to notice, is the cooling and comforting effect it has in oppressively warm weather in the summer time. Simply running the fan will, of itself, greatly relieve the oppressiveness, and when cold water is circulated through the coils the difference is very noticeable.

To sum up: The proper heating of factory buildings is of as much importance and involves as many problems as anything the manager has to decide. It is as essential as the transmission, tools or light, and very much more complex. It should be considered with the plans of the building and made an integral part of the construction, having in mind all the time the equipment best suited to the type of building and the purpose for which it is built.

Fresh air is essential to life. Man can clothe himself to withstand cold, but he cannot get along without air. The purer it is, the better health he has and the faster and better he can work. Therefore, any heating system which does not provide for fresh air should have no consideration.

Something in the way of a ventilating plant is required where manufacturing processes generate steam, smoke and gases. Cold air only makes bad matters worse, so the ventilation necessarily becomes a part of the heating system.

The subject of the proper temperature to maintain in shops is one that does not receive the careful attention it should. It is, if anything, worse to overheat a shop than to underheat it. A fair average temperature should be arrived at and the heating system be flexible enough to keep the shop comfortable when the temperature outside is above and below average.

The distribution of the heat is very important and must be varied with the nature of the building and the work done within its walls. Consideration must also be given to the air velocities, for the purpose of ventilation.

While the cooling of a building is not of the utmost importance, it certainly has great advantages in many ways, and if a system makes it possible of accomplishment without complication or great expense, it becomes a valuable asset to any plant.

These advantages, more or less amplified in the foregoing, as well as many others which have been covered by various writers, all point to but one system of heating as best adapted to manufacturing plants, and that one is the blower system. While it is quite generally recognized as the best, the proper way to install is not so generally understood, and to give some superficial ideas along this line was what prompted the foregoing.

The ventilation of public buildings, assembly halls, churches, schools, etc., require special study to adapt the system to the plans of the building in a way that will be least offensive architecturally and still provide the proper distribution of fresh air.

The velocities must be much lower in such buildings than is allowable in factories, to avoid noise, drafts, etc. It has become quite the common practice to allow the following velocities to prevail in various parts of the plant:

Heater and tempering coils....	800 to 1200 ft. per min.
Main distributing ducts........	600 to 900 ft. per min.
Vertical flues	400 to 600 ft. per min.
Registers or grilles............	300 to 450 ft. per min.

The velocity of air through the fan discharge can be anywhere from 1500 to 2500 feet per minute. The velocity of the tips of the fan blades should never exceed 4000 feet for absolutely noiseless operation.

The amount of air required in public buildings is usually dependent upon the number of occupants, and this is generally far in excess of the amount which would be required to heat it, if considered strictly as a heating problem.

Space herein available will not permit covering public buildings in detail. Volumes have been published on the ventilation of buildings under this classification, to which the inexperienced should refer for a broader knowledge of the subject, as this article is intended to cover the practical side and not the theoretical aspect of the subject.

Ventilation, Gravity System.

When the amount of air required per hour is known, the following rules may be used for low-pressure steam systems:

.02056 H. U. required to heat 1 cu. ft. of air 1°.
1.439 H. U. required to heat 1 cu. ft. of air 70°.
Total H. U. required ÷ 350 = sq. ft. indirect steam radiation. for 1st floor.
Total H. U. required ÷ 325 = sq. ft. indirect steam radiation for 2d floor.
Total H. U. required ÷ 500 = sq. ft. indirect steam radiation for 3d floor.
Velocity at all registers 3 to 4 feet per second.
Velocity in heat flues 1st floor 3 to 4 ft. per second.
Velocity in heat flues 2d floor 5 ft. per second.
Velocity in heat flues 3d floor 6 ft. per second.
Velocity in heat flues 4th floor 7 ft. per second.
Velocity in vent. flues 1st floor 6 ft. per second.
Velocity in vent. flues 2d floor 5 ft. per second.
Velocity in vent. flues 3d floor 4 ft. per second.
Velocity in vent. flues 4th floor 3 ft. per second.

The cubic feet of air per hour divided by velocity per hour = area of flue in square feet.

When the temperature of steam is 216°, cold air enters at 0°, the total heat-units given off per square foot indirect steam radiation per hour = 486.

The above rules are based on what may be expected at registers in rooms in which they are located.

If a velocity of 6 feet per second is maintained, a square foot of indirect radiation emits 3.25 heat-units per hour per degree difference between the temperature of steam and surrounding air at radiator. This may be taken as the limit of work for a square foot of indirect steam radiation with natural draft.

To determine boiler capacity divide the total heat-units required for all work by 280; the result will be the work equivalent in direct steam radiation, as per the conditions on which boilers are rated by the manufacturer.

Amount of Air Used for a Blower System for Ventilation.

	Cubic feet per hour.
Hospitals	3,600 per Bed.
Legislative Assembly Halls	3,600 per Seat.
Barracks, Bedrooms and Workshops	3,000 per Person.
Schools and Churches	2,400 per Person.
Theaters and Ordinary Halls of Audience	2,000 per Seat.
Office Rooms	1,800 per Person.
Dining Rooms	1,800 per Person.
Toilet and Bath Rooms	2,400 per Fixture.

Making Tight Screwed Joints for Very High Pressure.

If the ordinary steam fitter was called upon to put up piping that should stand 200 or 300 pounds of steam pressure, I think he would feel that he was taking a very large responsibility, and if he was called upon to do a job that should stand 1,000 pounds of air pressure he would not feel like taking this responsibility, and any one taking this responsibility would feel that he was obliged to resort to very extraordinary means in order to accomplish such a result, and if called upon to do such work with the ordinary material that is manufactured and supplied in the general market, he would say that it was an impossibility to do it.

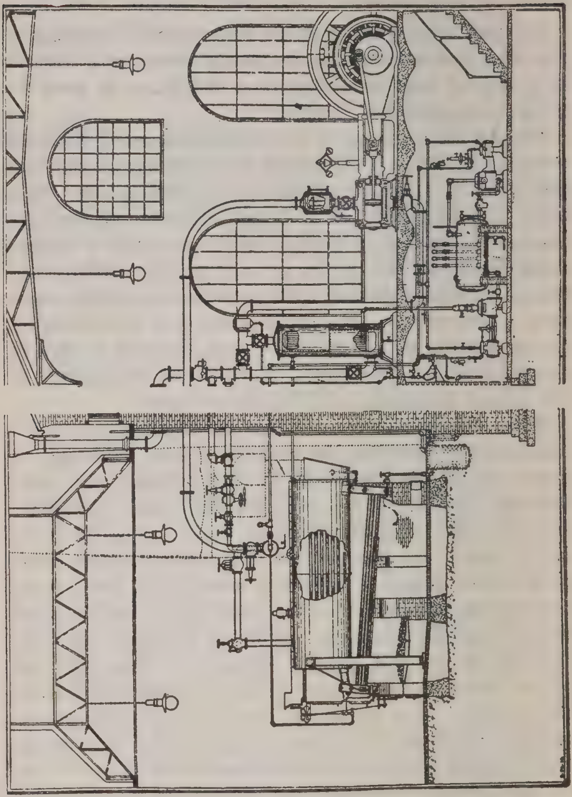
Friction is due to the large amount of surface, especially when the joints are coming up close to a bearing. Any grit or gummy material in the joint also tends very largely to produce friction. Friction produces expansion, and as the pipe is lighter than the coupling it expands more than the coupling, and then when both again become cool the pipe shrinks more than the coupling, thus causing a tendency to leak.

It is of course evident to anyone who has given any thought whatever to this subject, that in order to make tight such joints as are mentioned above, the iron must be brought together as solidly as possible.

To get such results it is imperatively necessary that the iron should be absolutely clean, and then it is essential that the very best lubricant is used in order to reduce the friction.

Would also add, that we have discovered that, in order to produce good joints, it is not necessary that the threads should be absolutely perfect, nor is a taper essential nor is a large amount of bearing necessary; in fact, we made one joint with a thread reduced to three-fourths of an inch in width, and this joint was tight at 1,500 pounds hydraulic pressure, which proves that the bearing was not essential to the making of a tight joint, and that the length of thread was not essential to prevent stripping of the thread from the coupling or the pipe.

This, I think, also proves another point that is not understood, and that is that it is not essential, in order to do good work, to have especially long threads. In fact, we are satisfied that especially long threads are a detriment in making a good joint, for it stands to reason that such long threads tend to produce friction, which prevents the iron from coming up closely together, and the irregularity of the thread on the pipe tends to prevent the iron coming up in the closest contact. This will be better understood, if we go to a great extreme in the matter. For instance, should we undertake to make a joint on eight-inch pipe, with a thread six inches long, the irregularities and friction would be so great that it would be impossible to get this thread contact.



Typical Layout of Power Plant Showing Combination Boiler, Water Tube, and Tubular, and all Necessary Piping.

Superheated Steam.

The subject of superheated steam has appeared in the forefront of engineering literature during the last few years as one of the most important factors in reaching the high degree of economy shown by some of our modern large power stations. Much has been said and written about the subject, but stated in simple words superheated steam is steam which has been heated above the boiling temperature without increasing the pressure at which it was boiled.

This is accomplished by passing it through the so-called super-heater just as the steam leaves the boiler proper, to go into the steam mains.

The superheater is composed of a number of tubes spaced closely (generally smaller than the boiler tubes proper), and exposed to the gases of combustion at a point when the gases are about half way on their passage from the furnace to the stack or breeching. The superheater may or not be constructed as an integral part of the boiler and must not be confused with the economizer which is sometimes installed in large plants, and which is located in a different place and used for an entirely different purpose.

The economizer is used for heating feed water and is usually placed between the boiler and the stack and utilizes the heat left in the gases after they pass.

The use of superheated steam in securing better economy in the operation of power plants has occupied the attention of engineers for a number of years, but owing to the serious difficulties accompanying its use it has been adopted generally only in the larger plants, where the fine points of design are looked after more carefully.

Superheated steam when used in the steam engine has brought about a remarkable improvement in the steam consumption by reducing the cylinder condensation. (By cylinder condensation is meant that steam when admitted to one end of a cylinder which has just been opened to the exhaust, the walls of which are comparatively cool, a part of this steam is then condensed to water and is therefore lost as far as useful work is concerned.)

On the other hand the troubles experienced in handling steam at such high temperatures have in many cases more than offset the advantages gained.

For example: Gaskets have leaked and blown out packings have deteriorated and cylinders have been scored under the sudden and wide variations of temperatures which are thus met with. But many of these troubles have now been overcome and the success of the steam turbine as a prime mover has established the use of superheated steam more firmly than ever.

With the steam turbine one of the main advantages in superheating lies in the decreased friction of the steam on the blades of the turbine. Furthermore, the erosion of the blades is reduced to a minimum. The exact gain in economy due to superheating the steam used in steam turbines is as yet not fully determined, but the saving is approximately 1 per cent for each 12½ degrees F. of super heat. After taking into account the increased cost of boiler plant with superheaters, and after allowing for increased cost of maintenance of the plant as a whole, the saving due to the use of superheated steam is beyond question an established fact.

Properties of Saturated Steam.

1 Gauge Pressure in Pounds per Sq. Inch	2 Temperature in ° F.	3 Total Heat in Heat Units from Water at 32° F.	4 Heat Units in Liquid from 32° F.	5 Heat of Vaporization in Heat Units	6 Density or Weight of 1 Cu. Foot in Pounds	7 Volume of 1 pound in Cubic Feet	8 Weight of 1 Cubit Foot of Water	9 Factor of Equiv'l't Evap'n from and at 212° F.
0	212.00	1146.6	180.8	965.8	0.03760	26.600	* 59.76 59.64	1.0000
10	239.36.	1154.9	208.4	946.5	0.06128	16.320	59.04	1.0086
20	258.68	1160.8	227.9	932.9	0.08439	11.850	58.50	1.0147
30	273.87	1165.5	243.2	922.3	0.10700	9.347	58.07	1.0196
40	286.54	1169.3	255.9	913.4	0.12920	7.736	57.69	1.0235
50	297.46	1172.6	266.9	905.7	0.15120	6.612	57.32	1.0269
55	302.42	1174.2	271.9	902.3	0.16210	6.169	57.22	1.0286
60	307.10	1175.6	276.6	899.0	0.17290	5.784	57.08	1.0300
65	311.54	1176.9	281.1	895.8	0.18370	5.443	56.95	1.0314
70	315.77	1178.2	285.6	892.7	0.19450	5.142	56.82	1.0327
75	319.80	1179.5	289.8	889.8	0.20520	4.873	56.69	1.0341
80	323.66	1180.6	293.8	886.9	0.21590	4.633	56.59	1.0352
85	327.36	1181.8	297.7	884.2	0.22650	4.415	56.47	1.0365
90	330.92	1182.8	301.5	881.5	0.23710	4.218	56.36	1.0375
95	334.35	1183.9	305.0	879.0	0.24770	4.037	56.25	1.0386
100	337.66	1184.9	308.5	876.5	0.25830	3.872	56.18	1.0397
105	340.86	1185.9	311.8	874.1	0.26890	3.720	56.07	1.0407
110	343.95	1186.8	315.0	871.8	0.27940	3.580	55.97	1.0417
115	346.94	1187.7	318.2	869.6	0.28980	3.452	55.87	1.0426
120	349.85	1188.6	321.2	867.4	0.30030	3.330	55.77	1.0435
125	352.68	1189.5	324.2	865.3	0.31070	3.219	55.69	1.0444
130	355.43	1190.3	327.0	863.3	0.32120	3.113	55.58	1.0452
135	358.10	1191.1	329.8	861.3	0.33150	3.017	55.52	1.0461
140	360.70	1191.9	332.5	859.4	0.34200	2.924	55.44	1.0469
145	363.25	1192.8	335.2	857.5	0.35240	2.838	55.36	1.0478
150	365.73	1193.5	337.8	855.7	0.36290	2.756	55.29	1.0486

*Formula observed.

The Blast Unit System of Steam Heating.

In many ways the modern industrial building presents a problem in heating different from any other type of building. The period of occupancy, due to the tendency toward short hours of labor, is probably less than any other type of building. The necessity for a heating plant which will quickly respond is therefore very great. Industrial buildings are usually constructed of glass, through which the heat loss is tremendous. The clear height from floor to roof is usually great, presenting a problem in holding the heat at the lower levels.

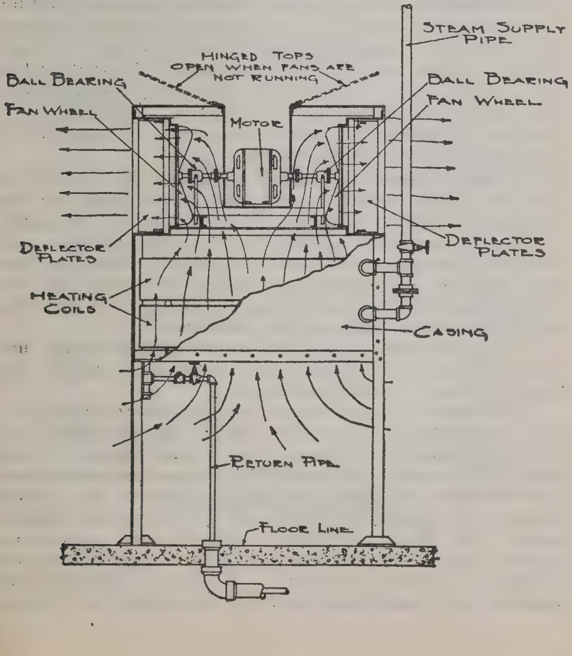
In the past, two distinct types of heating apparatus were used for industrial buildings. The most commonly known is the direct steam system. Radiators and pipe coils are usually placed along the exposed walls and roof of the building. This system is advantageous primarily because of its simplicity. Results are largely a matter of sufficient surface, and a system of piping which will carry steam to the different units of radiation. The chief disadvantage of the direct system lies in the fact that the operating cost is excessive because of the tremendous loss by radiation through exposed surfaces. Authorities generally agree that not less than 25 per cent of the total heat generated is lost in this manner. The direct system is also very slow to respond, and in most instances necessitates heat supply over the full twenty-four hours in order to maintain a comfortable temperature through the working hours.

The direct system does not readily lend itself to temperature control. Because of the length of time required to heat up a radiator or coil, and the corresponding length of time required for the same unit to cool, control of temperature by the operation of steam valves is unsatisfactory. In practice the temperature is usually controlled by opening and closing the windows, which is obviously an expensive, wasteful method.

The other type of system is what is commonly known as the blast or indirect system of steam heating. The heating surface is located at one or possibly two points in the building, and the air in the room is circulated over the heating surface by means of a blower. Heated air is distributed throughout the building by means of a system of sheet metal piping. This system overcomes a great many of the disadvantages of the direct system. It eliminates to a great extent the losses by radiation. It readily lends itself to temperature control by means of the control of air temperature leaving the heating surface.

The disadvantages are that the initial cost of the blast system is considerably greater than the direct system. The cost of motive power for driving the blower is high by reason of the friction to the flow of air in an extended system of air piping. The blast system of this type must be designed for the particular building in which it is placed. This applies to every part of the system. The design of a blast system necessitates the very best of engineering knowledge along these lines. Such factors as the resistance to the flow of air, the probable loss in temperature by connection and radiation from the air piping, must be determined with a reasonable degree of accuracy. The fact that a large percentage of blast systems are faulty is evidence of the care that must be given to the design of such a system.

Because of the large volume of air which must be


STEAM SUPPLY PIPE
HINGED TOPS OPEN WHEN FANS ARE NOT RUNNING
BALL BEARING
FAN WHEEL
MOTOR
BALL BEARING
FAN WHEEL
DEFLECTOR PLATES
DEFLECTOR PLATES
HEATING COILS
CASING
RETURN PIPE
FLOOR LINE

handled in a building of any size, the air ducts necessary are correspondingly large, and it is sometimes very difficult to design a blast system so that these ducts do not obstruct light and interfere with shafting, machinery, etc.

The past few years have witnessed the development of a heating system for industrial buildings which, to a very great extent, incorporates the advantages of both the direct and blast systems, with but very few of the objectionable features of either. This system is generally known as the blast unit system of steam heating.

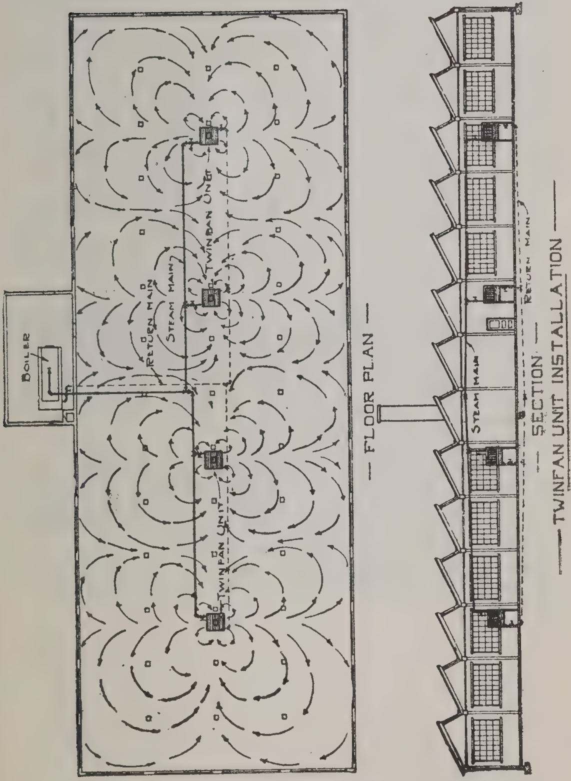
It consists of a number of units of varying size and number to meet the individual requirements. Each unit contains a group of steam coils, together with a motor and fans for distributing the heated air. The units are usually located near the center of the building, and are arranged to discharge heated air towards the exposed walls. Each unit is a complete heating machine in itself, entirely independent of other units in the same building.

In common with the blast system, the unit system eliminates the losses by radiant heat, one of the chief sources of loss with the direct system. The unit system uses power for circulating the air over the heating surface only. No air piping is necessary. For this reason the cost of power is usually one-fourth to one-fifth of the cost with the blast system.

The unit system is perfectly adapted to temperature control. The system is operated with steam in the coils at all times during the heating season. A supply of heat is available instantly by starting the fans, and may be shut as quickly as it is started. The fact that heat supply is instantaneous makes it certain that the temperature will be controlled by cutting off the heat supply instead of opening the windows.

The initial cost of the unit system is invariably less than the cost of the blast system, and is usually less than the cost of the direct system.

A feature of prime importance is that the nature of the unit system is such that results are absolutely certain. The capacity of a unit is definitely known. Every part of a properly designed unit is in perfect proportion, which makes possible a mechanical efficiency very seldom equaled in a plant designed for an individual requirement. The heating problem with the unit system resolves itself to the common problem of determining the quantity of heat necessary. Knowing definitely the quantity of heat which will be delivered by a given


BOILER
RETURN MAIN
STEAM MAIN
TWINFAN UNIT
TWINFAN UNIT
— FLOOR PLAN —
STEAM MAIN
RETURN MAIN
— SECTION —
— TWINFAN UNIT INSTALLATION —

Simplified Heating Plant

unit, it is a very simple matter to determine the size and number of units necessary for any building.

Like any mechanical device, the construction of a unit heater, to be highly efficient, is a matter of considerable thought and expert knowledge of both heating and mechanical engineering. The success or failure of a heating unit is dependent upon a great number of factors. Among these are the proper air velocities through the heating coils, and from the outlets, the type, size and pitch of fans, the accurate determination of the power requirement, the application of a motor of maximum efficiency for the duty, the arrangement of the heating coils, fans, etc., so as to properly proportion the machine and reduce friction to a minimum.

The unit illustrated is the Twinfan unit manufactured by the Gillespie-Dwyer Company of Chicago. This unit is made in two types, so that it may be set on the floor or suspended from above as required. The heating coils in this unit are laid flat in the housing and are set so that the air intake is relatively close to the floor. In this way air temperature entering the unit is at the lowest point. This unit is equipped with two fan wheels direct connected to an electric motor. The fans discharge air in opposite directions from the unit. The unit housing is arranged so that the motor is not exposed to the heated air currents.

The fans are carried on dustproof ball bearings, which are the only bearing surface inside the unit. Each outlet is provided with a set of deflector plates individually pivoted. This arrangement makes possible spreading or confining of the heated air as required.

The units are made in a number of sizes with a capacity from 150,000 to 650,000 B. T. U. per hour.

MECHANICAL REFRIGERATION AND ICE MAKING

Mechanical Refrigeration

Mechanical refrigeration is the process of reducing and keeping the temperature of a body or substance below the temperature of the atmosphere without the use of ice. In order to reduce such temperature it is necessary to employ a medium of lower temperature, which will absorb the heat. Liquids having a low boiling point are used as refrigerants. Carbonic anhydride (carbonic acid) and ammonia are used as refrigerants.

Carbonic anhydride evaporates at the low temperature of 124 degrees below zero Fahr. under atmospheric pressure and during evaporation absorbs from its surroundings a quantity of heat corresponding to its latent heat of evaporation. In other words, while water boils at 212 degrees Fahr. under atmospheric pressure, and about 250 degrees at fifteen pounds pressure; liquid carbonic anhydride boils at 124 degrees below zero Fahr. under atmospheric pressure and at 30 degrees Fahr. under a pressure of 34 atmospheres. Ammonia boils at 28 degrees Fahr.

The boiling point of water being far above the atmospheric temperature, heat must be applied to bring it to the boiling temperature. The boiling point of liquid carbonic anhydride and ammonia being very much lower than the temperature of the atmosphere, they absorb from their surroundings the necessary heat to cause them to boil or evaporate.

Refrigeration is produced by the ebullition of the refrigerant which is circulated through the cooling coils and returned to the refrigerating machine.

The cycle of operation is the compression, liquefaction and evaporation of the carbonic anhydride or ammonia.

The refrigerating plant comprises three parts.

1. A compressor in which the gas is compressed.
2. A condenser in which the compressed warm gas imparts its heat to cold water and liquefies.
3. Expansion coils in which the liquid re-expands into its original gaseous state, thereby absorbing heat and performing the refrigerating work.

In order to make the operation continuous the three parts are connected; the charge of gas originally put into the machine being used over and over again going progressively through the process of compression, condensation and evaporation. Thus only a small quantity of gas is required to replace any losses.

The compressor draws the gas from the expansion coils, compressing it to the liquefying pressure (which pressure depends upon the temperature of the cooling water in the condenser). The compressed gas is discharged into the condenser where it imparts its heat to the water in the condenser and becomes a liquid. This liquid is then returned to the expansion or cooling coils, expanding through same and thereby absorbing heat.

The surface of the cooling coils is so proportioned that all of the liquid evaporates as it passes through same. From there the gas again returns to the compressor to resume the cycle of operation. The pressure of the gas in the coils is controlled by means of a valve.

Direct Expansion System.

In the direct expansion system extra heavy wrought iron pipe coils are placed in the rooms to be cooled, either on ceiling, walls or in lofts built for this purpose. Connections are made between the coils and liquid receiver at outlet of condenser. An expansion or regulating valve is placed between the small liquid pipe and large expansion coils. The liquid is fed through the expansion valve and allowed to expand through the coil to a gaseous state. During its evaporation the carbonic anhydride or ammonia absorb heat from the surrounding atmosphere and then return to the compressor.

For general cold storage plants, breweries, packing houses, candy factories and similar plants the direct expansion system is preferable. It is the simplest system, requires less machinery, is more efficient, needs less attention and for these reasons is used where possible. With carbonic anhydride the direct expansion system can be used in many places where it would not be advisable with ammonia. In case of a leak in the expansion coils with the carbonic anhydride system no damage can result, while with the ammonia system the result might be disastrous.

Brine System.

The brine system is an indirect method of refrigeration; the carbonic anhydride or ammonia do not evaporate in coils placed in the rooms to be cooled, but instead evaporate through coils placed in an insulated steel tank, or through double pipe brine coolers.

Brine is made by dissolving calcium chloride in water; in some instances common salt (sodium chloride) is used. This brine is cooled by circulating it through a double pipe cooler or tank equipped with carbonic anhydride or ammonia coils and then pumped through the coils in the different refrigerators and rooms. The brine absorbs heat in passing through the coils and upon returning to the cooler it imparts this heat to the carbonic anhydride or ammonia.

In plants with a large number of small refrigerators, where the pipe runs are long, it is cheaper to install the brine system, as brine piping costs less than direct expansion piping. When the refrigerating machine is not operated at night and even temperatures are required, the brine pump may be kept running, circulating the brine which is still cold.

Whether the brine or direct expansion system should be used, depends entirely upon conditions, which should be thoroughly investigated before either system is installed.

The Manufacture of Ice.

There are two methods of ice making, namely, the can system and the plate system, both of which offer special advantages under certain conditions.

The Can System.

In order to produce clear and pure ice by this method, it is necessary to distill the water used for freezing, so as to free it from all organic matter, air, disease germs, etc. The distilling apparatus which serves this purpose is therefore a very important factor in an ice plant. The distilling plant comprises a steam separator, steam condenser, skimmer, reboiler and flat cooler. The steam separator is connected to the exhaust pipe from the steam engine. All impurities, such as grease, etc., carried by the exhaust steam, are removed and then the vapors are passed through a steam condenser, over which the waste water from the gas condenser is allowed to flow. After leaving the steam condenser the condensed water passes through a skimmer where most of the impurities are removed. The condensed, distilled water contains air and sometimes other volatile substances, possessing more or less objectionable odor. To free it from this, the water is subjected to a vigorous re-boiling in a separate tank. The distilled and re-boiled water is then passed through a flat cooler, over which the cold water passes, and its temperature reduced.

As a still further means of purification, charcoal filters are used, through which the water passes into a storage tank provided with a direct expansion coil. In this tank the water is cooled as near to its freezing point as possible and is then drawn off and filled into the ice molds or cans, which are immersed in a tank filled with brine. Cooling coils are submerged in this tank, through which the expanding gas travels, absorbing the heat from the brine and reducing it to the required low temperature of 12 to 15 degrees Fahr. The brine in the freezing tank is well agitated, causing an even temperature throughout and slowly freezing the water in the ice cans. After the ice is frozen solid, the can is hoisted out of the tank (by a hoisting apparatus, which is movable) and conveyed to the thawing apparatus, where the ice in the can is loosened from it (either by immersing the can into a bath of warm water, or by an automatic sprinkling and dumping apparatus) and discharged into the storage room.

The Plate System.

The plate ice system has an advantage in that it is not necessary to distill or boil the water if otherwise pure. The ice, which forms slowly on hollow freezing plates immersed vertically into tanks filled with water, purifies itself of any air or other impurities. On the other hand, it is an established fact that the plate system requires more skill to operate successfully and the plant is generally more expensive to install and keep in repair. Local conditions, price of coal, quality of water, etc., determine which system should be given the preference.

The plate system embraces three distinct types. The brine plate system, in which the direct expansion coil is submerged in brine between two plates a few inches apart, the brine acting as a medium of contact between the direct expansion pipes and the plates, the ice freezing on the outside of the plates.

In the dry plate system, the gas coil is clamped between two plates which are rapidly cooled by direct expansion coils, the ice forming on the plates.

The third system is the block system, in which the water freezes directly to the bare direct expansion coils, from which it is harvested by cutting it into blocks with a vertical steam cutter.

The freezing time required for a plate ten to twelve inches thick is from six to eight days. After the ice has formed to the required thickness it is loosened from the plates, hoisted out of its compartment, cut into blocks of proper size and discharged into the storage room.

This system of ice-making is independent of the use of steam, except the small amount required for loosening the ice ends in the compartments and for cutting the ice plates, so that electric or water power can be applied wherever available at a low rate.

The evaporation or expansion of the carbonic anhydride takes place in coils of extra heavy wrought-iron pipe. For brine tanks, water coolers, small refrigerators and rooms the pipes are welded into coils of continuous lengths and in large rooms the pipes are connected by flange unions.

Safety.

In connection with the high pressure side of the cylinder is a safety valve for the purpose of insuring against accidents. This safety valve is placed in the high pressure channel between the gas discharge valves and the discharge stop valve. The purpose of this valve is two-fold. It will relieve the cylinder and also the system of a pressure that has risen above the normal in case of a fire or through lack of condenser water, and it will also guard against carelessness of the operator who might attempt to start the machine without first opening the discharge stop valve. As the action of the safety valve is accompanied by a loud report it will direct the attention of the operator to the machine. When the pressure again becomes normal this valve closes automatically. This safety valve is designed to blow off at a pressure considerably below that at which the machines are tested.

The time of freezing a certain cake of ice depends largely upon the amount of water to be frozen.

Cakes 8 to 11 inches thick require from 38 to 54 hours, with brine at 14 to 15 degrees Fahr.

All water for condensing and cooling purposes goes through a series of operations. It is first used on the gas condenser, then on the steam condenser and cooling coils of the distilling outfit and finally, when quite warm, it is used for feeding the steam boiler.

The best arrangement of an ice factory operating on the can system, with distilled water, is to locate the gas condenser high enough to allow the water used on same to flow by gravity to the distilling apparatus and down to the feed water heater.

The inlet and outlet of the cylinder are provided with stop valves by means of which the system can be shut off, allowing access to the cylinder without loss of gas from any part of the system.

Ice manufacturing, 10 to 20 above zero.

One ton of good coal will make 6 tons of ice.

Ice Machine and Its Power.

One and one-half to two H. P. will take care of a ton machine in the small class, such as butcher shops, creameries and cold storage.

Handy Information for Mechanical Refrigeration.

Joints.

The way in which the piping is attached to the fittings is interesting. The piping of strictly wrought iron comes to us from the mills with plain ends, cut in exact lengths. Upon receiving an order in our shops for a stock of condensers, the pipe is carefully threaded to suit the fittings. A workman then grinds the pipe on an emery wheel about 1-inch back of the thread. While this is being done the fittings are allowed to swim in a solder bath; directly next to this is a bath of tin, in which the threads are thoroughly tinned. The fitting is taken from the solder bath and placed in a positive position in a form. The pipe is then screwed into the fitting, after which the recesses in the return bend and the threads exposed are thoroughly solder-covered and in cooling, the pipe and fitting shrink into practically a homogeneous mass.

After cooling, this pipe is fitted with a blank flange on one end and to the other end is attached an air connection, admitting from 300 to 400 pounds of air. The pipe is next submerged in a tank of water, when any leak present would be indicated by bubbles on the surface of the water. All pipes which do show leakage, are at once rejected. The result of this painstaking process is that leaks and the Triumph ammonia condenser are not found together.

Cost of ice for cooling 2700 cubic feet, $50 per month.

Cost of mechanical refrigeration in same plant, $5 per month.

The double pipe type of ammonia condenser is in use in far more than 50 per cent of the plants built today—evidence that this style of apparatus is giving abundant satisfaction under almost every condition an ammonia condenser must meet.

2000 pounds of melted ice is called a ton of refrigeration.

About 50 to 60 pounds of steam per hour per ton of ice.

8 gallons of water per ton per minute for 50 tons of ice, 400 pound cans.

10 pounds of ice can be made from a pound of good coal.

10 to 12—400 pound cans to the ton.

14 to 16—300 pound cans to the ton.

100 tons of refrigeration, 60 tons of ice making.

The Ice Tank.

Not many years ago, tanks of wood were considered satisfactory for ice making service. This is no longer true, however, since thoroughly seasoned lumber has become more and more scarce and expensive. Then, too, tanks of steel offer advantages lacking in the wooden construction.

The steel sheets may be easily transported and erecting labor is considerably reduced by using the metal tank. When correctly installed, the durability of the metal tank cannot be surpassed.

The steel tank which is used is usually of ¼ inch material, from 3 to 6 feet deep, depending upon the size of cans.

ICE MAKING.

To manufacture one ton of ice in 24 hours requires about two tons of refrigerating capacity, due to radiation losses from brine tank, heat absorbed by cooling of water to freezing point, latent heat absorbed by freezing of water into ice, and cooling of ice from freezing point to temperature of brine in ice making tank, etc. In the United States, in many towns of over 20,000 inhabitants the amount of ice consumed per year is one ton per person. The consumption is less than half a ton yearly per person in towns having a large foreign element and where the public have not been accustomed to the use of ice.

Time Required for Freezing Ice.

Inside Dimensions of can in inches	Pounds Weight of Cake	Brine Temperature 10°	16°	20°
		Hours to Freeze		
4½x11x26	25	10	16	21
6 x12x28	50	12	20	25
8 x16x31	100	24	36	45
11 x22x32	200	37	55	69
11 x22x44	300	44	60	74
11 x22x57	400	44	60	74

Coils in Ice Tank.

Brine Temp.	Gas Temp.	NH_3 Suction Lbs. Gage	CO_2 Suction Atm. Gage	Lineal Feet 1¼" Coil in tank per Ton of Ice
10°	0	16	21	245
16°	6	20	23	245
20°	9	23	24	245

With 25% higher suction pressues allow 300 lineal feet of 1¼" per ton of ice.

Horse Power Required.

Two electrical horse power input into electric motor per ton of refrigeration is required for small ammonia or carbonic machines up to twelve tons capacity with a temperature of about 70° Fahr. inlet water to condenser, and maintaining temperatures of about 35° Fahr. in the refrigerator room, or when cooling brine in a tank from 10° to 15° Fahr. Larger units require less horse power per ton. In large electric driven raw water ice plants 45 to 65 kilowatt hours per ton of ice manufactured is required, which includes power required by auxiliaries; the higher the temperature of brine in ice tank, the less power required per ton of ice manufactured. The higher the suction gauge pressure the less the horse power per ton in compression systems.

Circulating Ice Water.

When cooling drinking water for department stores, office buildings, hotels and other public buildings, allow 5 tons refrigerating capacity for every 100 gallons water per hour consumed, thus allowing for waste and radiation losses through water pipe covering. In hotels with fountains in every room allow one ton total refrigerating capacity for 50 to 75 rooms. Drinking water fountains in corridors of public buildings are opened so often that one ton of refrigerating capacity is required per every six to eight fountains. Two gallons of drinking water per minute is usually circulated per ton of total refrigerating plant capacity. In office buildings having drinking fountains in every office allow one ton capacity per 40 fountains.

MODERN METHODS OF COOLING DRINKING WATER

By American Carbonic Machinery Co.

Factory superintendents, architects and engineers, who are most active in utilizing modern methods of doing things right, consider that factories and buildings should be equipped with a mechanical refrigerating plant for cooling drinking water.

The old bucket and dipper method, or common drinking cup, is not only unsanitary, expensive and wasteful of time, but on account of the temptation to drink excessive quantities at infrequent opportunities it affords, has proven very injurious.

Lack of proper supply of water at improper temperatures lowers the personal efficiency, and decreases production of the employee.

The new method is to install a sanitary, porcelain, self-closing bubbling cup, in combination with a carbonic system of refrigeration.

Ice vs. Mechanical Refrigeration: According to accurate cost records of one of the largest American corporations, it was discovered that the old fashioned ice water cooler is 300% more expensive to maintain than a mechanical refrigerating plant, considering the excessive cost of ice, and labor for handling ice, as compared with the cost of power and supplies for a refrigerating plant. The electric power required is only one kilowatt maximum demand per 100 employees.

Water Pipe Line Design: The ideal plant to install is the self-closing, bubbling fountain, interconnected by properly insulated pipe lines, through which water is recirculated at a velocity not exceeding 195 feet per minute. The water, after traveling through not more than two thousand feet of pipe, usually rises about five degrees in temperature, when it should be returned to refrigerating plant and recooled. Physicians agree upon this point, that water at a temperature of 40 to 45 degrees Fahr. is most acceptable, as it acts as a mild heart stimulant and reduces the temperature of the body.

Quantity of Water: Factory hands performing very hard manual labor, such as required in steel mills, consume and waste one quart of water per hour per man. In other industries where lighter manual labor is required, an allowance of one pint per hour per person is a safe estimate, including waste.

Pipe Covering: Commercial cork drinking water pipe covering is made of material of such thickness and quality as to permit a maximum transmission of 4 to 7 B. T. U.'s per lineal foot of pipe per degree difference per twenty-four hours. Ample allowance for this loss must be made before deciding upon capacity of ice machine.

Sulphur Dioxide

Sulphur dioxide boils or vaporizes at 14 degrees Fahr. under atmospheric pressure or zero pounds gauge pressure. At higher pressures the temperature of vaporization is also higher; at lower pressures this temperature is reduced. The normal condensing pressure is about 50 pounds.

Soldered Joints.

Soldered joints may be made in a number of ways, one of which will be described. Muriatic acid is used, a few pieces of zinc having been dropped in the vessel containing it to make the acid work. Powdered sal ammoniac is used to make the solder flow freely and the tools required are: an iron spoon to distribute the solder, and a soldering hook made of iron or copper wire about ¼ inch in diameter, with the end flattened and bent at an angle so that it can be placed in the recess of the flange to be filled with the solder. Before making the joint, all oil should be wiped off the threads and the pipe should be filed clean for an inch or more back of the threads. The flange or fitting is then screwed on tightly and, together with the pipe, is heated with one or more blow lamps. As soon as the parts are heated enough to flow solder, a little acid is poured into the recess back of the flange and acts to remove all grease and dirt. This being done, a small amount of solder is flowed into the recess and rubbed against the surfaces with the soldering hook. In this way the solder is made to take hold of the iron and the use of the hook eliminates the burnt acid and any particles of dirt that may be present. Having tinned the surfaces in this way, the recess back of the flange is filled with solder, a little sal ammoniac being used to keep the solder fluid. While the solder is being poured, the blow lamp must be used to keep it flowing so that all parts of the recess are filled evenly. When this has been accomplished and the solder has hardened, the joint is washed thoroughly to remove any traces of the acid and a coating of rust-proof paint is applied. From this it will be seen that the process of making the soldered joint is simple, being nothing more than the act of filling in the recess cut out in the back of practically all flanges used in ammonia piping work.

The shrunk joint is the most thorough and at the same time the most expensive of all the methods of making pipe connections. The process of making the joint consists of heating the pipe and fitting in a charcoal fire, rubbing the parts to be joined in sal ammoniac for a few seconds and then plunging them into a pot of melted solder. From the pot, the parts are taken again to the sal ammoniac and thoroughly rubbed, after which they will be found to be perfectly tinned. The pipe is then allowed to cool while the fitting is kept hot and screwed on in the heated condition, it being somewhat expanded owing to the heat. The fitting must be screwed on quickly and tapped with a hammer while being turned so that there is no chance for it to cool or for a film of solder to be formed between the joining surfaces. The idea is to have the solder fill up all imperfections and holes but not to form a film between the joining surfaces as is the case where the lead was disconnected and a spare one put in place.

The Refrigerating Machine.

The refrigerating machine is the heart and soul of the plant and should be of the best design, with proper proportions to give the required capacity when operating under the local conditions of the plant. The compressor with its driving engine or motor is placed in the machine room with the water pumps and other auxiliary apparatus, while the condenser is placed on the roof of the building under a cover or in the third story of a tower as shown in Fig. 16. With this arrangement the water from the ammonia condenser can be passed over the exhaust steam condenser to take up heat from the steam before passing to the feed-water heater and thence to the boilers. As shown in Fig. 16, the ammonia and steam condensers are of the atmospheric type, which is in general use. The cooling water is run over the top pipe of the coil and drips down over the lower pipes until collected in a trough under the coils. About 80 square feet of cooling surface is allowed per ton of ice made in 24 hours.

Where space is limited and the condenser must be placed in the building with other machinery, the spray from water flowing over the coils is objectionable and the double-pipe condenser is used. This is nothing more than a coil of pipe within a coil, so that an annular space is formed between the two pipes forming the double coil. Ammonia enters this space at the top of the coils and flows downward, while the cooling water enters the smaller pipe at the bottom and flows upward. Thus the coolest water is in the part of the coil containing the hottest ammonia and the highest possible efficiency of heat transfer is had. Submerged condensers, consisting of a pipe coil in a tank filled with water, may be used if circumstances require, but this form of condenser is difficult to clean and requires a large amount of cooling water. Also it is difficult to detect leaks, as the leaking ammonia is absorbed by the water. Where the water supply for the condensers is not as cool as could be desired, good results may be had by rigging the double-pipe condenser so that water can be run over the outside of the coils as in the case of the atmospheric condenser.

Compressors are made both single and double acting and have the cylinders either horizontal or vertical. The driving engine should be of the Corliss type with a good releasing valve gear, so that the steam consumption will not be so great that more distilled water is made than is needed for the ice cans. In all except the smallest units and in some designs of extremely large machines, the engines are direct-connected to the same crankshaft as the connecting rods of the compressors. Both simple and compound engines are used and are run condensing or non-condensing as may be required by the local conditions. Where compound engines are used, the cylinders may be connected in tandem or they may be cross-connected, the latter method being preferred for large machines and for machines of the vertical type where two single-acting cylinders are used. The connecting rod of the engine may be connected to the same crank pin as that of the compressor, or it may be on a separate crank of the same shaft.

In small vertical machines having one compressor cylinder, the engine may be set vertical and be connected to the opposite end of the crank shaft from the connecting rod of the compressor, a flywheel being placed on the middle of the shaft. One form of the horizontal machine is that in which the engine is connected to one end of the shaft, the other end of which drives two single-acting horizontal compressors. In still another arrangement, the engine is connected to the middle of a shaft on each end of which is a crank that drives a compressor of either the horizontal or vertical construction. In all of the different arrangements, flywheels are used to give steady working, being placed in various ways according to the disposal of the other parts of the machine. Very large units sometimes have a band wheel on the middle of the crank shaft between the two compressors so that the machine may be driven by belt from a separately mounted engine of proper size.

It is important that the builder of a plant should understand the relative advantages and disadvantages of the different types of construction so that he may make a selection of a machine suited to the conditions under which it is to be operated. It is evident in the first place that the stuffing-box of the single-acting machine can be kept tight easily because it is subjected only to the comparatively low pressure of the suction gas instead of the pressure of the condenser, which ranges from 125 pounds upward. On the other hand, the double-acting compressor is more economical because, at each revolution of the crank shaft, it deals with almost twice as much gas as a single-acting machine of the same cylinder diameter and stroke. With the exception of the extra friction resulting from the necessarily tighter stuffing-box gland of the double-acting machine, the friction of the two machines is the same. Notwithstanding this extra friction, it is estimated that, in comparison with a machine having two gas compressors, the amount of saving with the double-acting compressor is one-eighth of the whole amount of power required to compress the gas.

As the double-acting machine is capable of doing the work of two single-acting compressors, there is considerable saving in the first cost for construction material. This saving is partly offset by the extra care and expense necessary to properly construct the double-acting machine and by the fact that this machine is rather complicated in the arrangement of valve ports and connecting passages. In any compressor it is important that clearance be made as small as possible consistent with safe working, and this is rather difficult to do successfully with the double-acting machine. In plants using a single machine and the direct expansion system, as where the gas is expanded direct in the coils of freezing plates used with the plate system of ice making, it is important that the compressor be kept in operation. On this account there is an advantage in having two single-acting compressor cylinders instead of one doubling-acting machine, as any accidental damage to one of the compressors can be remedied while the other is kept in operation. By running the single cylinder at increased speed, the plant will make capacity, whereas with the double-acting machine it would be necessary to shut down and allow the temperature of the freezing tank to rise until the machine could be put in operation again.

In considering the relative value of the horizontal and vertical types of machines, it is seen that the vertical machine has the advantage in that the parts wear uniformly. In compressors other than those using the oil injection, the least possible amount of oil is used, and prevention of undue wear on any of the parts is an important consideration. Vertical machines are not subject to bottom wear of the pistons, as are horizontal compressors in which the weight of the piston is supported by the lower part of the cylinder wall. In the horizontal machine, the tendency is to wear the cylinder into an oval shape and to reduce the diameter of the piston until leakage occurs past it. This kind of leakage is difficult to detect and is often neglected. As the cylinder wears, part of the weight of the piston is supported by the stuffing-box gland when the piston nears the crank end of the stroke. This causes unequal wear on the stuffing-box glands so that it is difficult to keep them tight. In the vertical compressor, the suction and discharge valves work up and down so that the wear on their stems is equal in all directions, thus ensuring correct and accurate seating at all times. Other things being equal, the engineer will give better attention to the horizontal machine because he can see any defect that may show up without having to climb a ladder to hunt for it. It costs more money to build a vertical machine, and for this reason a horizontal machine is in favor where floor space is plentiful. In the end it will be found that the cubic feet of space occupied by machines of the two types is about the same, so that it all depends on which kind of space, vertical or horizontal, is more valuable.

Loss of Liquor.

After a machine has been in operation for some time, the liquor level in the generator may show a tendency to fall until, by restoring it with increased speed of the ammonia pump, the level in the absorber falls out of sight in the gauge glass. This will occur without any apparent cause, the density of the rich liquor meantime remaining standard at 26 degrees. In a new plant, this may be due to insufficient charge, but if after supplying more liquor to restore the proper level in both generator and absorber, the level falls again, something must be done. As a first move the cooling water and the brine in the bath should be tested with litmus to see if there has been any leakage. If the trouble is not found to be leakage, it must certainly be due to some of the liquor being pocketed in a low place in the piping system or in the expansion coils where these are not laid out for the gravity return to the absorber. In such a case, the liquor will be drawn over by making a vacuum on the absorber as in the case of a boil-over. If it is found that there are no leaks and none of the ammonia is pocketed in the coils, the trouble must be due to air in the topmost pipes of the condenser and cooling coils, which has gradually found its way into the absorber and been burnt at the purge cock.

Making Up Ammonia Losses.

Aqua ammonia should at all times be kept up to the standard density of 26 degrees, and if the ammonia pump is in first-class order a somewhat higher density may be used to advantage up to about 28 degrees. The greater the density, the easier the gas is liberated and in case the density has fallen below standard, to say, 24 degrees, aqua or anhydrous ammonia must be added. The amount of ammonia to be added may be found by consulting the percentage table in Chapter IV, in which it will be seen that aqua ammonia at 26 degrees density contains in round numbers 28 per cent of pure anhydrous ammonia and at 24 degrees density 24 per cent of ammonia, the loss being 4 per cent of pure ammonia. Supposing, for example, that the original charge was 10,000 pounds, 28 per cent of which or 2800 pounds is pure ammonia, we have then to supply 4 per cent of this quantity or 112 pounds of liquid anhydrous ammonia to bring the density of the whole charge up to 26 is restored. Where the freezing tank is elevated to give the gravity return to the absorber, this will be all that is necessary, but otherwise it will be necessary to close the poor liquor valve on the absorber, and start the pump to create a vacuum in the absorber, so that the ammonia will be drawn over from the expansion coils. After the coils are emptied of the liquid, the weak liquor valve to the absorber is opened and the pump kept running in the regular way, or at reduced speed if necessary to keep the liquor in the generator at the proper level. As the temperature of the bath will rise during the righting of the distribution of ammonia in the system, the machine will require special attention until normal conditions have been restored.

Vacuum Test.

To make the vacuum test, the air remaining in the system is pumped out to form a vacuum of 28 or 29 inches, as already mentioned. In doing this, the stop valve on the discharge pipe of the compressor is closed as are also all the valves of the system that communicate with the atmosphere. Communication is made with the atmosphere between the compressor cylinder and the stop valve on the discharge line, this being done by an air valve provided for the purpose or by opening a flange connection as was done on the suction line for the pressure test. All valves connecting the different parts of the system are opened and the machine is started to pump out the air in the pipes. When the desired vacuum is obtained, the machine is left standing for about 6 hours to see if there are leaks of air into the system. If in this time no leaks are indicated by a fall in the vacuum, the joints may be considered tight and preparations may be made to charge with ammonia.

Before making the pressure test of the system, it is well to test the steam, water, waste, and exhaust steam piping and connections to see that all joints are proof against leakage. Live steam is turned into the steam pipes and a moderate back pressure is had in the exhaust piping by setting the back pressure valve or by throttling the exhaust with stop valves where there is no back pressure valve. Water pipes are subjected to a pressure about 30 per cent in excess of the ordinary working pressure by partially closing the stop valves on the pipes near the condenser and the inlet to the water jacket of the compressor.

When the piping connections of the entire system have been made and the machinery has been set up, adjusted, examined, and found in good condition with the stuffing-box gland properly packed, the plant is ready to be tested for leaks under both internal and external pressure. It is customary to subject the system to internal pressure for the first test and after all leaks that show up in this test have been mended the air may be pumped out until the system shows a vacuum of about 28 or 29 inches. To make the pressure test the stop valve on the suction line is closed and the valves provided between it and the compressor to connect with the atmosphere are opened. Where no such valves are provided, a flange joint between the stop valve and the compressor cylinder may be broken and held open with wedges to admit air to the system. All other valves of the system except those communicating with the atmosphere as at the drains of oil traps, etc., are opened so that the pressure when raised will be equalized over the entire system. Provision is made to lubricate the compressor piston with the smallest possible amount of mineral oil that will prevent the piston rings from seizing and if the interior of the cylinder cannot be lubricated in any other way, the heads must be removed and the oil smeared over the inner walls. The heads are then replaced and the bolts set up evenly and tight.

Making Tight Joints for Ammonia Work.

Select good strong piping of reliable manufacture, the next point is to see that the threads are properly cut. All threads on the ends of pipe and in fittings should be cut true and sharp and if cut on the lathe, should be chased with care. If a die stock is used, it should be in the best of condition with the dies good and sharp. No amount of doctoring with solder, lead or other joint-making materials will do any good if the threads are not properly cut and the parts accurately fitted together. Solder has its place in joint making where the joint is to be permanent, but in work of this kind all the greater care should be taken to have the threads properly cut. Where the threads are so poorly cut that they do not fit down closely into the grooves, ammonia has no trouble in leaking out and solder can do little or no good; as it is impracticable to sweat it into all the openings in the threaded joint.

A joint having threads of this kind presents a great temptation to a careless workman or an unscrupulous contractor to jam the two parts of the joint together in an effort to make the joint hold. In doing this, the pipe is screwed into the fitting further than it should go, so that the threads are stripped or additional threads are cut on the pipe. In this way the workman may make a joint that will hold until the contractor gets off the job and out of reach, when it becomes the duty of the unfortunate engineer to shut down the plant or impair its operation by cutting part of the piping out of service for mending the bad joint. Generally it will not be a case of mending, as the threads on the pipe and in the fitting will be found damaged beyond repair so that new threads must be cut on the pipe and a new fitting purchased. Probably the best way to avoid such troubles as this is to have the engineer, who is to operate the plant, on the ground during its erection. If he is a competent man and is given authority to have the work properly done, there will be little trouble in store for the future.

After all, the simplest way to make joints in an ammonia piping system is not to make them. That is to say, every joint that can possibly be dispensed with should not be made, and as few fittings as will do the work should be used. One of the readiest methods of eliminating joints is the use of pipe bends instead of elbows and return bends. It costs money to bend pipe, but where every joint eliminated may mean the saving of several pounds of ammonia, the price of which quickly runs up into dollars, the increased first cost by using the bent pipe system is of no material consequence. Pipe bends require more space than ordinary elbows and return bends, but the piping may usually be arranged so that little if any additional ground space need be bought.

Even if the pipe bends should necessitate larger buildings and more ground space, there are compensating advantages, one of which is reduced friction of the gases and liquid ammonia passing through the pipes, so that a greater back pressure may be carried with a resulting increased efficiency. Then again there is better provision for expansion and contraction where the bends are used, so that strains in the pipe line are largely eliminated and there is less likelihood of leaks being sprung. The number of joints, used in a plant where the bent pipe system is adopted, depends on the lengths in which the pipe can be manufactured and handled and to some extent on the use to which the pipe is put. In the case of a condenser, for example, where the pipe comes in the same length as the coils are to be made, there will be one joint for every length of pipe instead of two as would be the case if return bends were used. These joints are alternated at opposite ends of the condenser on every other pipe of the coil and are placed about 2 feet from the end of the condenser.

Making Brine.

When ready to make the brine, the tank should be filled about two-thirds full of water and the apparatus for mixing the salt with the water should be put in place. This may be nothing more than an ordinary barrel having a false bottom about 4 inches above the real bottom. Water is admitted to the space between the two bottoms and flows through ¼-inch openings with which the false bottom is perforated into the upper part of the barrel, which is filled with salt to within about 6 inches of the top. A pipe connection for carrying off the brine is made to the upper part of the barrel and a box strainer is placed in the space above the salt over the pipe opening. A well is provided in this strainer box for the hydrometer, and the water supply must be so regulated that this instrument registers 90 degrees. The apparatus may be placed in any convenient position, as on the floor of the tank room and is simple and inexpensive. It may also be used when the brine is to be strengthened at any time during service. Water is supplied to the bottom of the barrel by the brine circulating pump where one is installed, and in lieu of this one of the water supply pumps may be connected for the purpose, the suction of the pump in any case being connected to draw from the brine tank. Where there is no brine pump, however, and the water pump has to be used, it may be more convenient to start with the tank empty and not partially filled as above instructed. In this case there is no necessity for making a suction connection from the tank to the pump.

Even under the most favorable conditions, some air will be present in the system after the vacuum test and for this reason it is advisable to charge the ammonia by degrees, about 70 per cent of the whole charge being pumped in at the first trial. After the plant has run some time and the ammonia has been well circulated through the system, the air will collect in the highest parts of the piping and may be exhausted at the purge valve on the condenser. The rest of the ammonia will be charged in one or two installments as may seem best under the circumstances. To disconnect the drum, close the valve on it first and then close the charging valve.

About one-third pound of ammonia should be used for each running foot of 2-inch pipe or its equivalent in the expansion coils, so that about 275 pounds would be required for a 25-ton plant. It is better to put in too small rather than too large a charge, as more ammonia can be added with little trouble at any time it may be needed. Too small a charge is indicated by the tendency of the delivery pipe of the compressor to heat and this should be watched carefully, the regulating valve being manipulated so that the normal temperature of the pipe is the same as that of the cooling water leaving the condenser.

Bending Pipe.

In adopting the bent pipe system, care should be taken not to bend the pipes on so small a radius as to injure them nor yet to make the radius so large that the bend looks ungainly and out of proportion. . Although some latitude may be allowed in making bends for certain locations, there should be uniformity throughout the system and the work of bending should be accurate, the turns being made exactly 90 and 180 degrees as the case may be. The bending radius, other things being equal, depends on the size of the pipe and when once a ratio of size of pipe to radius of bend has been decided on, it should be adhered to as far as practicable. Otherwise the plant will present the spectacle of a small pipe, bent on a large radius, along side of a larger pipe bent on a smaller radius. Nothing could be more unsightly. All pipes must be heated before bending and if there is any doubt about the pipe being able to stand the strain of bending, it should be filled with dry sand and capped on the ends before heating. This will insure a smooth bend without kinks. As a precaution against opening the weld, the line of the weld should be put on the side of the bend.

Why Is Raw Water Ice Clear?

Produces pure clear ice by keeping the water in movement or in agitation while it is being frozen. Process does this by feeding a small jet of air through the freezing water from below, and in this way keeping it stirred or in a state of gentle ebullition. When so agitated while freezing, the ice naturally and of necessity freezes crystal clear.

Freezing clear ice from raw water by keeping it agitated with air is not new, but is many years old. Apparatus is so constructed that this essential air feed is outside of the cans and not exposed to the action of cold brine, and hence can never be interrupted by freezing up, which would result in white or opaque ice, until the trouble was located and corrected. Very little power is needed for this air feed, about a cubic foot of air per minute per ton capacity under a pressure of from 3 pounds to 3½ pounds is all that is needed.

Temperature of Brine and Time to Freeze.

To produce cakes of standard weight, from 50 pounds to 400 pounds, as desired, but the 200, 300 and 400-pound cakes are preferably only 10 inches in thickness, and the preferred temperature of the brine is zero or thereabouts. The fact that there is a positive forced circulation of this cold brine in the jackets of the can results in greatly shortening the time of freezing, and a 10-inch cake of either of the above standard weights, is frozen nearly solid in about 18 hours, and the freezing progresses to a solid cake and the ice is tempered and harvested in 4 more hours, thus completing the freezing, tempering and harvesting of the larger cakes in 22 hours, which allows a margin for the completion of the freeze and the starting of another within the 24-hour period.

The plants are built in separate units or batteries, each producing a certain fraction of the daily product required, the proportion represented by each unit to the daily quantity to be produced, depending on the size of the plant. A 5-ton plant would thus be built in two or three units. A 30-ton plant in six units, or separate batteries, and in still larger plants the units or batteries may run up as high as 20 or 25 tons in each battery. One of these units is usually being tempered and harvested, while the others are freezing.

Hotels and Restaurants.

Refrigerating plants are now being used in leading hotels and restaurants with the best of success. They are particularly well adapted to the requirements where there are a variety of refrigerators to be kept cool. One plant will cool the large meat storage, the vegetable and general storage, the short order box, bakery or pastry box, fish and oyster box, ice cream box, beer storage and back bar, if necessary. It will also make the requisite ice for table use and will cool the drinking water — in fact, do any cooling that is required.

The sanitary feature of a hotel plant cannot be over-estimated, to say nothing about the saving of waste because of improper cooling, and the satisfaction of being able to keep goods day after day in the best of condition without the use of ice with its expense and attendant discomforts.

Creamery Plants.

Refrigerating plants in creameries are usually installed with a brine system. The brine tank is located in the upper part of the cold storage room, keeping the air cold and at the same time furnishing brine to be run through ripeners and milk and cream coolers. The brine is supplied to the apparatus requiring it by use of a brine pump. It is not necessary to run the ammonia compressor all day, but only long enough to reduce the brine to the required temperature; then when the milk is ready to be cooled, the pump is started and circulates the cold brine to do the necessary work.

The creamery man knows the importance of being able to control the temperature of cream during the ripening process regardless of weather conditions. To be able to turn out a fine uniform grade of butter, a refrigerating plant is a valuable asset—in fact, it is necessary to properly control temperatures. One of our plants will soon pay for itself in labor, cost and increased value of product. To creameries using power for other purposes, the cost of operating a refrigerating plant is very light, as about the only expense is the power and a few cents for oil.

The storage of perishable food stuffs, such as fruits, vegetables, butter, cheese, eggs and poultry, has revolutionized commerce in edibles. It has meant preservation for long periods, transportation for long distances, and re-storage until required, thus making it possible for dealers to buy in quantities when prices are low, without fear of deterioration before sale.

Cold storage, in connection with refrigerating or ice-making plants, has become common and a very profitable business. Many wholesalers of beer and soft drinks, that will preserve their value only in cold temperatures, are using artificial refrigeration for this purpose.

Artificial Refrigeration.

During the past ten years the science of artificial refrigeration has had a very remarkable growth, due to the fact that the experimental element has been to a large extent eliminated.

The refrigerating machine manufacturers have in their own factories made extensive tests on the various types of machines, now offered to the trade; with the result that the prospective purchaser of this class of machinery will receive the apparatus best suited to his particular needs.

At the present time the larger consumers of ice, such as ice cream manufacturers, retail butchers, etc., are exceedingly active in the installation of small machines to furnish the required refrigeration. The many advantages of mechanical refrigeration over the old method of ice, or ice and salt, is in a large measure responsible for this condition.

With a small outfit the butcher is able to maintain lower temperatures in his refrigerator, as well as to keep both the meat and box in a better condition. As an advertising medium, the refrigerated showcase is without an equal, permitting the shopkeeper to display his commodity without becoming contaminated by the handling of his many customers and without deterioration while being displayed in this manner, which is the case in the ordinary display methods, and the loss subsequent thereto.

It is not necessary to operate the refrigerating plant continuously; by installing brine congealing tanks, a sufficient quantity of refrigeration can be stored in these tanks while the plant is in operation, so that during the periods that the machine is shut down, proper temperatures may be maintained in the compartments refrigerated.

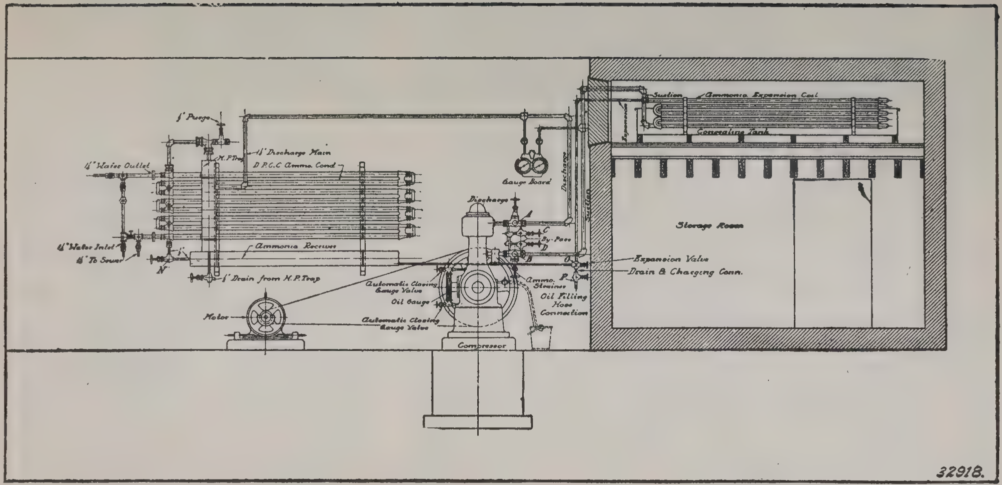
The ice cream manufacturer makes use of mechanical refrigeration for the freezing of ice cream, hardening of the same after it is frozen and for the manufacture of ice, which is necessary for packing the cream for delivery to the consumer.

Unit of Capacity.

Real ice-making capacity depends upon the temperature of water to be frozen, and can be calculated as follows:

Assuming water to be frozen is 80° F. on a one-ton plant, we have 2,000 lbs. of water from 80° = 32° which, in B. T. U. equals 2,000 × 48, or	96,000
Latent heat, 142 B. T. U. per lb. is equal to 2,000 × 142, or	284,000
Ice from 32° — 10° specific heat, .5 equals 2,000 × 22 × .5, or	22,000
Or a total of	402,000

However, there must be added to the above a liberal percentage for losses through insulation, tank covers, etc. Say about 40% for plants from one to fifteen tons capacity and 18% to 25% on larger factories.


½" Purge
1¼" Discharge Main
H.P. Trap
D.P.C.C. Ammo. Cond.
1¼" Water Outlet
1¼" Water Inlet
1¼" To Sewer
N
½"
Ammonia Receiver
½" Drain from H.P. Trap
Motor
Gauge Board
Discharge
Suction
Discharge
A
C
By-Pass
D
B
O
P
Automatic Closing Gauge Valve
Oil Gauge
Automatic Closing Gauge Valve
Ammo. Strainer
Oil Filling Hose Connection
Compressor
Expansion Valve
Drain & Charging Conn.
Suction
Ammonia Expansion Coil
Expansion
Congealing Tank
Storage Room
32918.

At the present time the enclosed type single-acting vertical oil enclosed refrigerating machine is the best suited for this class of work that has yet been manufactured. They are made both steam and belt driven, as well as single and double cylinder, according to capacities required, and are built in sizes ranging from one-half ton to twenty tons refrigerating capacity. The belt driven machines can be operated by any power available, such as electricity, gasoline or gas engine, or water power.

The manufacturers of these small machines have endeavored to build an outfit that will meet a wide range of conditions, with the result that these machines are partically "fool-proof." It is not necessary to employ experienced help to operate these small plants, and with a reasonable amount of care and judgment in operation, the results obtained are so much better than those secured by the old methods, that it is a question of only a short time until mechanical refrigeration will be used by every up-to-date retail butcher and ice cream manufacturer.

The uncertainty of the natural ice crop, which is so often of a poor quality, and the inadequate supply of artificial ice in many localities, together with the high prices which prevail under these conditions, makes, to the large consumer of ice, a necessity of what but a few years ago was considered a luxury—a small mechanical refrigerating plant to replace the use of ice.

Standard Ice Making Units

Capacity Lbs.	Cans	Weight Lbs.	Rows	Outside Dimensions
180	3	60	1	7′ 4″ x 2′ 6″ x 4′ 1″
360	6	60	2	7′ 4″ x 3′ 2″ x 4′ 1″
360	6	60	3	5′ 10″ x 3′ 10″ x 4′ 1″
540	9	60	3	7′ 4″ x 3′ 10″ x 4′ 1″
720	12	60	3	8′ 10″ x 3′ 10″ x 4′ 1″

Size of cans 5″ x 14″ x 32″

Mechanical refrigeration to the market is no longer an experiment—it is a necessity, and once a plant is installed, the owner will never go back to the old, unsatisfactory, wasteful and unsanitary method. He knows that he has refrigeration when he needs it; his stock is in much better condition and can be held for a much longer time; choice cuts can be aged without deterioration; veal and pork do not get wet and slimy.

Temperature Required to Preserve in Cold Storage Various Articles of Food.

The table of approximate temperatures given below will give you an idea of the purposes for which ice making and refrigerating machinery can be employed with profit to its users.

ARTICLES	DEG. FAHR.
Apples	30-36
Asparagus	33
Bananas	55
Beans, fresh	32
Beans, dried	45
Beef, fresh, short carry	35
Beef, fresh, long carry	30-32
Beer, in barrels	33
Beer, in bottles	45
Berries	36
Butter	14
Butterine	20
Cabbage	33
Cantaloupes, short carry	40
Cantaloupes, long carry	33
Carrots	33
Cheese	33-38
Chocolate, dipping room	65
Cider	32
Celery	32
Cigars	42
Corn, dried	34
Cranberries	33
Cream	33
Cucumbers	38
Currants	32
Dates	55
Eggs	32
Figs	55
Fish, fresh water, frozen	18
Fish, salt water, not frozen	16
Fish, to freeze	5
Flowers, cut	36
Fruits, canned	40
Fruits, dried	40
Game, short carry	28
Game, after frozen	10
Game to freeze	0
Ginger Ale	36
Grapes	36
Honey	45
Hops	32
Huckleberries, frozen	20

ARTICLES	DEG. FAHR.
Ice	28
Ice Cream, short carry	15
Lemons, short carry	50
Lemons, long carry	36
Lambs	32-40
Lard	40
Livers	20
Maple syrup and sugar	45
Meats, salt, after curing	35
Mutton	32-40
Nursery stock	30
Oleomargarine	40
Onions	32-35
Oils, cotton seed	35-40
Oranges, short carry	50
Oranges, long carry	34
Oxtails	30
Oysters, in tubs	25
Parsnips	32
Peaches	36
Pears	33
Peas, dried	40
Plums	33
Pork	30
Potatoes	34
Poultry, short carry	28
Poultry, after frozen	10
Raisins	55
Ribs, not brined	20
Salt meat, curing room	32
Sardines, canned	35
Sausage casings	20
Scallops, after frozen	16
Shoulders, not brined	20
Sugar	45
Syrup	45
Tenderloins	33
Tomatoes, ripe	42
Watermelons	32
Wheat flour	40
Wines	45
Woolens	28

Refrigerating Capacity for General Cold Storage.

ZERO ROOMS.

Cubic Feet Room	Direct Expansion Cubic Feet of Space per Lineal Foot of Coil Ratio		Tons Refrigeration Running 24 Hours daily.	Fresh Goods Stored. Llbs.
....	1¼″	2″	..	......
1,000	1.3	1.8	2	2,000
3,000	1.6	2.2	5	6,000
6,000	1.9	2.8	8	10,000
10,000	2.5	3.8	10	12,000
20,000	3.4	5	15	18,000
50,000	6.5	9.5	20	22,000
100,000	7.1	10	36	40,000

Rooms insulated with 8″ pure cork board. Calculate each room separately.

Average specific heat of food products 0.78.

ROOMS 35° FAHR.

Cubic Feet Room	Ratio Direct Expansion		Ratio Brine Circulating	Tons Refrigeration	Hours Run	Fresh Goods Stored daily Lbs.
....	1¼″	2″	1¼″	....	..	......
350	2	...	2.5	½	12	......
1,000	2½	3.2	2.2	1	12	2,000
3,000	3	4.5	3.4	3½	12	6,000
6,000	4.2	5	3.8	6½	12	10,000
10,000	4.4	5.5	3.9	10	12	12,000
20,000	10	14	9	10	24	18,000
50,000	18	22	16	15	24	22,000
100,000	25	33	24	20	24	40,000

Rooms insulated with 4″ pure cork board. Each room should be calculated separately.

Average specific heat of food products 0.78.

Beef Cooling.

A hog weighs about 275 lbs., a beef carcass about 700 lbs., a calf 95 lbs., and a sheep about 80 lbs. The capacity of hog, beef or sheep coolers should be at least of capacity to take care of two days' maximum killing.

Cold Storage Boxes and How to Build Them.

Artificial refrigeration has in the last ten years or so, to a great extent, taken the place of cooling with ice. It is much cleaner and convenient and also cheaper.

With a machine it is possible to keep the temperature at all times to within a few degrees of the temperature wanted. Nowadays we find in all up-to-date butcher and grocery stores, etc., also in hotels, big and small and even in modern apartment houses, the cooling of boxes done by means of a refrigerating machine. These machines are of two kinds, one using ammonia, the other carbonic acid gas (called CO2).

The best refrigerating rooms and boxes are made of pure cork boards. The most approved way of building these rooms or boxes is shown in the accompanying plan view of a refrigerating box. The walls are always erected of two thicknesses of 2″ cork boards with a ½ inch to ⅝ inch thick Portland cement mortar coat between.

Care should be taken to break joints both horizontally and vertically. The exposed cork surfaces should be covered with expanded metal and receive two coats of Portland cement plaster. The first coat being a scratch coat, the second a float or smooth finishing coat. Ceiling and floor should also have four inches of cork insulation. For boxes located in a basement, when floor in the box is to be level with floor outside of the box, excavate to a depth of ten inches below the floor grade and lay a four inches thick concrete bed of the same size as the outside dimensions of the box. Then lay two thicknesses of two inch thick cork boards with a half inch cement coat between, breaking joints both ways. On top of the cork boards lay a 2½ inch thick cement floor, ¾ inch of this being a finishing coat.

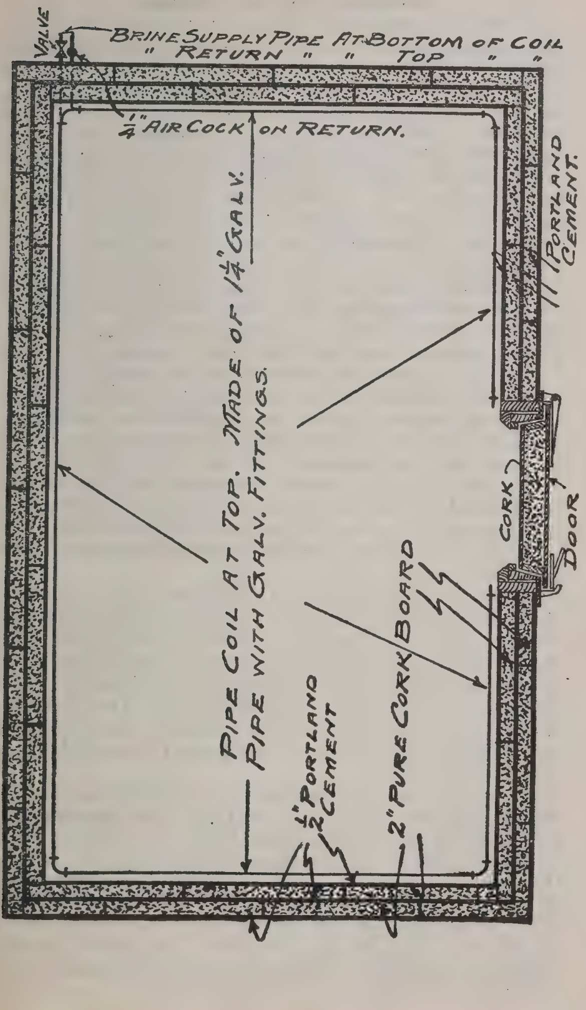
The floor of the box should be ¾ inch to one inch higher than the floor of the basement to prevent water running in. Cement floor should not be laid until the walls are erected. If box is built on a wood floor then lay two thicknesses of heavy water proof building paper. The first dry, the second in hot asphalt cement on the wood floor, then two layers of two inch thick cork boards as described before, or they can also be laid in hot asphalt cement. After the walls are erected, put in the 2½ inch thick cement floor. Ceiling of a box is made as follows:

After the walls are up to the required height, nail a 2″ x 6″ wall plate to the top of the four cork walls, then place 2″ x 8″ joists on 18″ centers. To the lower edge of the joists nail a ⅞″ thick D. & M. flooring. Apply either hot asphalt cement or Portland cement mortar to the cork boards and nail them securely to the flooring. The second layer of cork boards should also be set in either hot asphalt cement or Portland cement mortar and also be nailed to the first layer of cork boards, as the nailing will hold the boards in place until the cement is set. Ceiling should also have a two coat cement plastering.

A very convenient way to apply the Portland cement plaster to the cork boards is to build a wood frame 18″ x 36″ inside dimension and 2⅝″ high (the size of standard cork boards), hinged together at one corner. Lay the frame on a table and insert the cork board, then fill in to the edge of the frame with the Portland cement mortar and scrape off. Open the frame, remove the board and place it on the walls or ceiling, as may be the case. When applying the boards to the walls or ceiling, rub them slightly back and forth and up and down, as they then will adhere better to the wall. It is well to use a straight edge to see that there are no low or high places. Should there be a high corner or side, it can easily be forced in with a hammer or mallet.

Cement mortar should be of the following proportions: One part of Portland cement to two parts of sharp clean sand. Doors and windows should be of what is called the "cold storage" kind and should never be of the home-made variety, as it is very important that they are air proof.

Doors are from 5″ to 6″ thick cork lined. Windows have triple glass, forming two air spaces. There are many manufacturers of this kind of doors and windows.


VALVE
BRINE SUPPLY PIPE AT BOTTOM OF COIL
" RETURN " " TOP " "
¼" AIR COCK ON RETURN.
PORTLAND CEMENT.
PIPE COIL AT TOP. MADE OF 1¼" GALV. PIPE WITH GALV. FITTINGS.
CORK
DOOR
2" PURE CORK BOARD
½" PORTLAND CEMENT

Insulation for Cold Storage

Several materials are manufactured for use as insulating materials for cold storage rooms, buildings, tanks, etc., where temperatures lower than the outside temperatures are to be carried. Previously to the time these materials were manufactured for this purpose, it was the practice to insulate these surfaces with an air space construction made by erecting alternate layers of sheathing, building paper, furring strips, etc., forming one or more air spaces, given the so-called name of "dead air-spaces." Another type of construction was the erection of suitable studding with one or more layers of sheathing and building paper nailed to each side and the space between the studding filled with mineral wool, sawdust or mill shavings. These constructions had the serious defect that moisture was condensed either in the air spaces or in the filling material, causing rapid deterioration of the insulation or building construction, and due to the accumulation of moisture, a great loss of insulating efficiency after same was in use one or more seasons. It was with the idea of overcoming the deposit of moisture in the material and with the idea of manufacturing an insulating material suitable for use in the modern type of masonry constructed building that the manufactured type was designed.

There are at the present time three types of manufactured material: the pure cork sheet, consisting of 100 per cent pure cork, the granules composing this sheet cemented together with natural cork gum; impregnated cork board made from granulated cork and a pitch binder; and a mineral wool type of sheet, having more or less variation from a composition consisting of mineral wool and peat, to mineral wool, peat and flax fibre.

For severe cold storage service, practice has shown that either the pure cork sheets or the impregnated cork boards are better adapted to the service and both are able to resist the absorption of moisture, thereby maintaining their insulating efficiency indefinitely, and also protecting the building structure from deterioration due to absorption of moisture. Of the two cork boards, the pure cork sheet is more efficient and better suited to general insulating conditions.

Where insulating sheets are to be erected against wooden surfaces one or more layers of insulating paper should first be erected, and a course of the cork sheets well nailed to the surface. If two courses are desired, it is recommended that the second course be erected against the first in a Portland cement bed, the same as tile or other similar material is erected, after which the surface can be given a surface coat of Portland cement approximately ½" thick. If the surface against which the insulation is to be erected is of masonry construction, either brick, concrete, tile or stone, the first course can be erected in a bed of Portland cement the same as described above, the second course erected in a similar manner and finished with Portland cement. The sheets may also be erected in a bed of hot asphalt, but this type of construction is not recommended generally, except for floors, for the reason that the average asphalt on the open market is liable to deterioration in time, due to evaporation of volatile oils, and also for the reason that the bond between the cork sheets and the asphalt is not as strong as between the cork sheets and Portland cement. In laying insulation on floors asphalt may be used to good advantage and is therefore recommended.

Any kind of a working floor suitable to the industry may be laid directly on top of the cork board. A concrete floor consisting of 2" of stone or cinder concrete and a 1" Portland cement top is most generally used. For work in breweries or other industries where considerable water is experienced, an inch and a half asphalt mastic floor is often used. Where a wooden floor is desired, suitable nailing strips may be let in the top course, to which any thickness of wooden floor desired may be nailed. If a sheathed surface is desired against the wall or ceiling insulation instead of Portland cement as described above, such a surface may be had by letting in the top course of cork sheets suitable nailing strips, to which the sheathing may be erected. It is to be noted, however, that this type of finish is now almost absolutely discarded in favor of the Portland cement, since it is likely to deteriorate under cold storage conditions, due to the moisture usually met with in this service.

Where the building is so designed that air-spaces will be formed, it is recommended that these spaces be filled with granulated cork so as to prevent the absorption of moisture, same as described above for dead-air space construction, which was formerly used.

For the insulation of brine and ice making tanks the floor on the tanks can be insulated with one or more courses of cork sheets, each course laid in hot asphalt and the top heavily coated with hot asphalt, after which the tank may be placed directly on top of the insulation. For insulating around the sides of these tanks two methods are suggested. One—the building of a suitable retaining wall either of brick or wooden sheathing, located the proper distance from the tank and the space between the retaining wall and the tank filled solidly with granulated cork. The other construction is the erection of suitable studding directly against the tank sides and nailing of sheet cork to the outer edge, and filling between the studding solidly with granulated cork and finishing the exposed cork sheets with Portland cement same as described above for cold storage rooms.

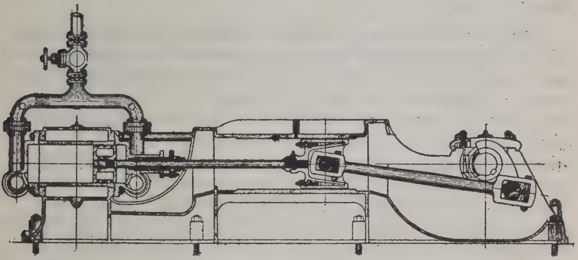
Experience has shown that the following thicknesses of sheet insulation are good practice:
For temperatures from 50 degrees upwards 2″
For temperatures from 32 to 50 degrees ... 3″
For temperatures from 20 to 35 degrees ... 4″
For temperatures from 10 to 25 degrees ... 5″
For temperatures from 0 to 15 degrees ... 6″
For temperatures from 0 and below ...... 6″ to 8″

The above thicknesses are good for rooms to which maximum refrigeration is applied 24 hours per day. If it is desired to maintain practically constant temperatures with the machine shut down, say 12 hours per day, one to two more inches of insulation should be erected than above given.

The care with which insulation is erected has a great bearing on the length of life and its value to the owner. Insulation erected by those not thoroughly experienced is liable to fall, is liable to collect moisture and be unsatisfactory regarding efficiency, appearance and length of life. All joints should be butted tight and properly broken so as to prevent passage of moisture or air through the insulation and all the work erected solidly and with the proper care.

The Raw Water System of Ice Making.

During the past very few years, the system of manufacturing ice direct from raw water, *i. e.*, undistilled water, has come into extraordinary favor, so much so that by far the greatest amount of installations in tonnage in new ice making plants has been (particularly in large centers) raw water and not distilled water plants. The reason for this is quite obvious, as, in the first place, raw water ice is—in many respects—superior to distilled water ice on account of its freedom from lubricating oils, boiler compounds and the consequent undesirable odors; secondly, because in ice made from raw water, all essential salts and beneficial chemicals are retained and not boiled off, as in the case in making distilled water ice. Thus, raw water ice results in a more palatable product by far—the difference in taste being detectable at once.



Electrically driven raw water ice plants are of extraordinary simple construction and possess these advantages: the up-keep and cost of repairs and supplies are nominal as compared with other types, the depreciation is less than half that of distilled water plants. The labor for operating a raw water plant is not required to possess any particular skill or knowledge and on account of the absence of the steam boiler, the fireman is eliminated. No coal or ashes need be bothered with and this also results in a greater degree of cleanliness and sanitation about the ice plant. Further, an electrically driven raw water plant can be located anywhere desired and not necessarily adjoining a railroad, unless, of course, the bulk of the ice is shipped; otherwise, particularly in large cities, such plants—to avoid long hauls in delivering—can be located directly within a residence district, as there is no nuisance, such as smoke or noise, connected with them.

Electric power companies have recently become enthusiastic over the possibilities presented by raw water ice plants as power users—because of the fact that such plants have a maximum demand for power when other demands, such as for light and street railway service, are at their lightest and vice versa. As a result electric power companies are encouraging the building of such plants, as they tend to balance up the electric power plant load and, in consequence, more attractive rates for electric current are quoted ice making plants than most any other industry.

The *elevation and ground* plan on preceding page of a 60 ton electrically driven raw water plant gives an idea of the neatness and compactness to which such an installation can be brought. It will be noted that the *ice machine* consists of two units, this being done to make the plant more flexible; that is to say, when operating the year round one of the *compressors* can be unhooked and remain idle during the late fall, winter and early spring, when ice consumption is at its low point, thereby cutting down the power bill during this period. In addition to the compressors, air blowers are supplied for agitating the water within the cans, also a core pump for removing the core water, which contains what minor impurities—not extracted by the filters—might remain in the water with which the cans are filled, these minor impurities having been cast off during the process of freezing into the unfrozen core, which is extracted through a special sucker tube connected by hose with the core pump. The core pockets are next filled with filtered water, so that each cake is frozen solid throughout and becomes exceptionally clear and crystal-like when finished. The usual propeller is found as in other plants for agitating the brine in the freezing tank. In the plant shown in the diagram a special type of electric crane is used, which has a capacity of lifting three 400 pound cakes at once, transporting them to the dip and dumping table on harvesting. The plant shown has—in addition—an electrically driven centrifugal water pump which pumps the water used on the condenser back over the cooling tower, the purpose of this being to economize on condenser water, which is used over and over again.

As water is supplied from city mains, which is charged for at meter rates, by means of the cooling tower, the consumption of water is limited to that which is actually converted into ice in the freezing process and the small amount required to replace that carried off by evaporation at condenser and cooling tower.

With a well-balanced plant—such as the one shown—the electric power consumed is very low compared with the ice output, a matter of from 35 to 45 K. W. hours per ton of ice produced. A very great advantage in electrically driven plants—which is also the case with any other type of refrigerating or ice making plant—is to provide abundant ammonia condensers for the purpose of keeping the high pressure down as low as possible and a very large can surface to permit of higher brine temperatures which—resulting in a slower freezing process—produces a better cake of ice and one not liable to crack in harvesting, and, what is of greatest importance, the bringing nearer together of the high and low ammonia pressures, results in a much lower power consumption per ton on account of the greater volume of ammonia gas being pumped while these pressures do not range so far apart.

The ice machines used in this installation are of an extraordinary type known as the SAFETY ammonia compressor, which has been patented and is manufactured by a number of reliable concerns throughout the country. A feature of the SAFETY compressor is the peculiar location of the suction and discharge valves, as will be noted on the skeleton drawing shown. The possibility of wreck and consequent loss or damage resulting from breakage of valve or the dropping of valve part into cylinder and also from liquid shock is by this construction entirely eliminated.

Electrical Units.

The electric units are as follows:

VOLT—The unit of electrical motive force.

Force required to send one ampere of current through one ohm of resistance.

OHM—Unit of resistance. The resistance offered to the passage of one ampere, when impelled by one volt.

AMPERE—Unit of current. The current which one volt can send through a resistance of one ohm.

COULOMB—Unit of quantity. Quantity of current which, impelled by one volt, would pass through one ohm in one second.

FARAD—Unit of capacity. A conductor or condenser which will hold one coulomb under the pressure of one volt.

JOULE—Unit of work. The work done by one watt in one second.

WATT—The unit of electrical energy, and is the product of the ampere and volt. That is, one ampere of current flowing under a pressure of one volt gives one watt of energy.

One electrical horse-power is equal to 746 watts.

One kilowatt is equal to 1,000 watts.

To find the watts consumed in a given electrical circuit, such as a lamp, multiply the volts by the amperes.

To find the volts, divide the watts by the amperes.

To find the amperes, divide the watts by the volts.

To find the electrical horse-power required by a lamp, divide the watts of the lamp by 746.

To find the number of lamps that can be supplied by one electrical horse-power of energy, divide 746 by the watts of the lamp.

To find the electrical horse-power necessary, multiply the watts per lamp by the number of lamps and divide by 746.

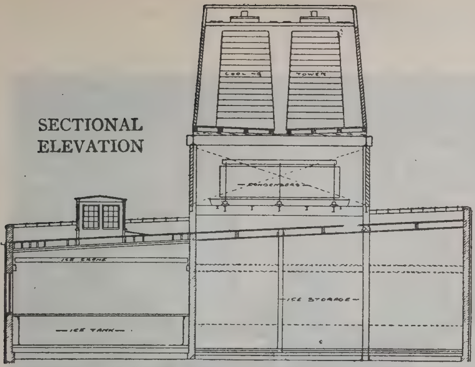
To find the mechanical horse-power necessary to generate the required electrical horse-power, divide the latter by the efficiency of the generator.

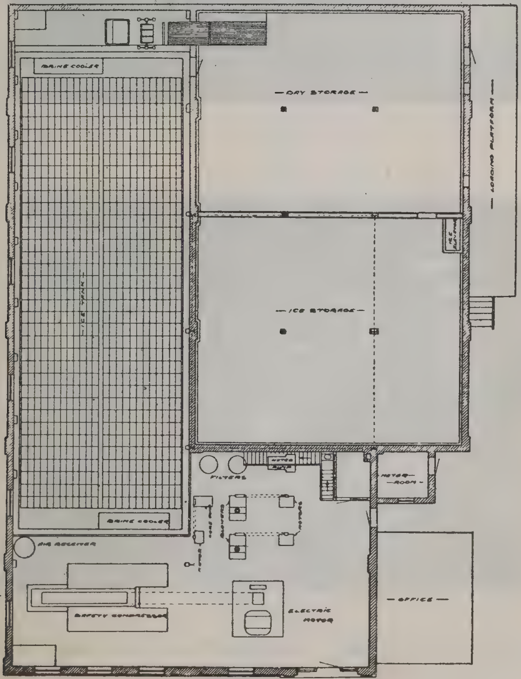
To find the amperes of a given circuit, of which the volts and ohms resistance are known, divide the volts by the ohms.

To find the volts when the amperes and watts are known, multiply the amperes by the ohms.

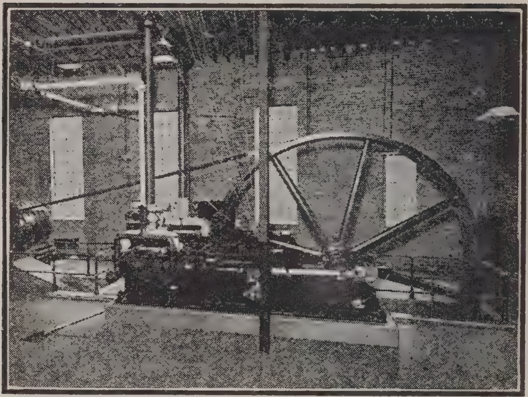
To find the resistance in ohms, when the volts and amperes are known, divide the volts by the amperes.

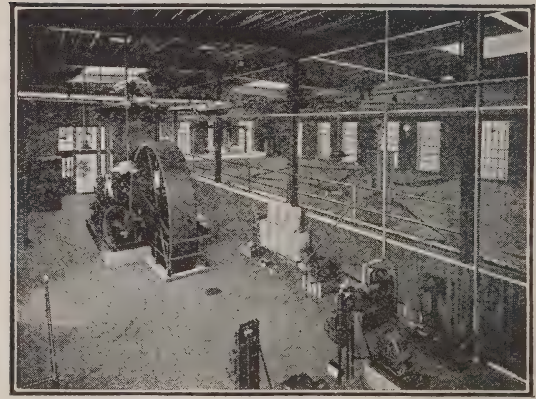
SECTIONAL ELEVATION


COOLING TOWER
CONDENSERS
ICE CRANE
ICE STORAGE
ICE TANK

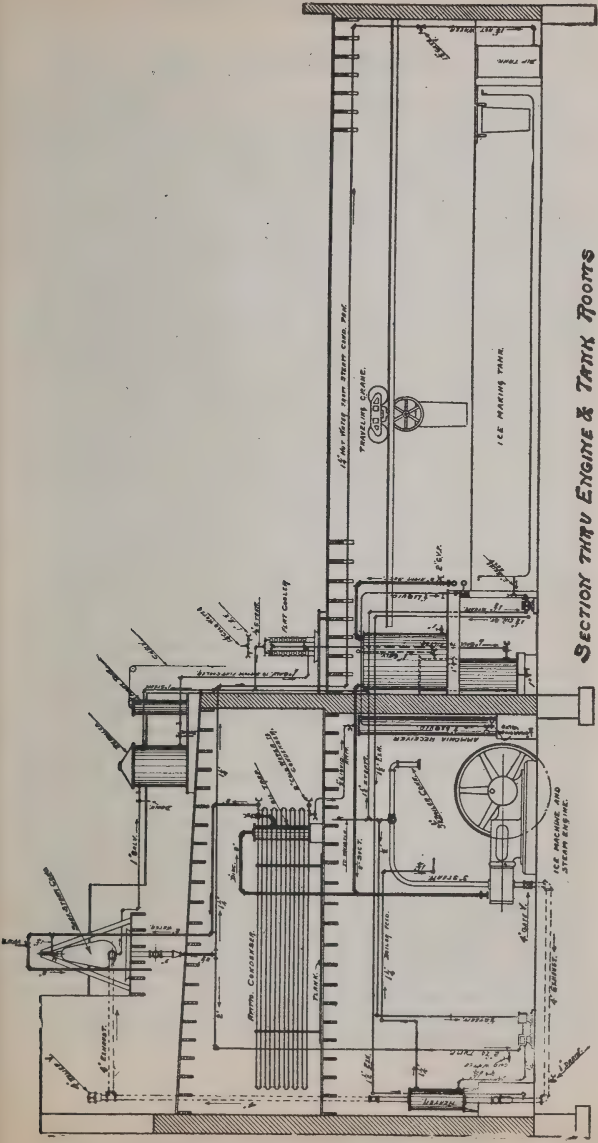

BRINE COOLER
DRY STORAGE
LOADING PLATFORM
ICE ELEVATOR
ICE TANK
ICE STORAGE
FILTERS
MOTOR PUMP
METER ROOM
BLOWERS
MOTORS
MOTOR
BRINE COOLER
AIR RECEIVER
SAFETY COMPRESSOR
ELECTRIC MOTOR
OFFICE

FLOOR PLAN





VIEWS OF A 60 TON RAW WATER ICE PLANT DESCRIBED ON PAGES 289-291


AMMONIA RECEIVER
ICE MACHINE AND STEAM ENGINE
TRAVELING CRANE
ICE MAKING TANK
1½" HOT WATER FROM STEAM COND. TAN.
FLAT COOLER
AMM. CONDENSER
PLANK
HEATER
DIP TANK
4" EXHAUST
1½" BOILER FEED
1" DRAIN

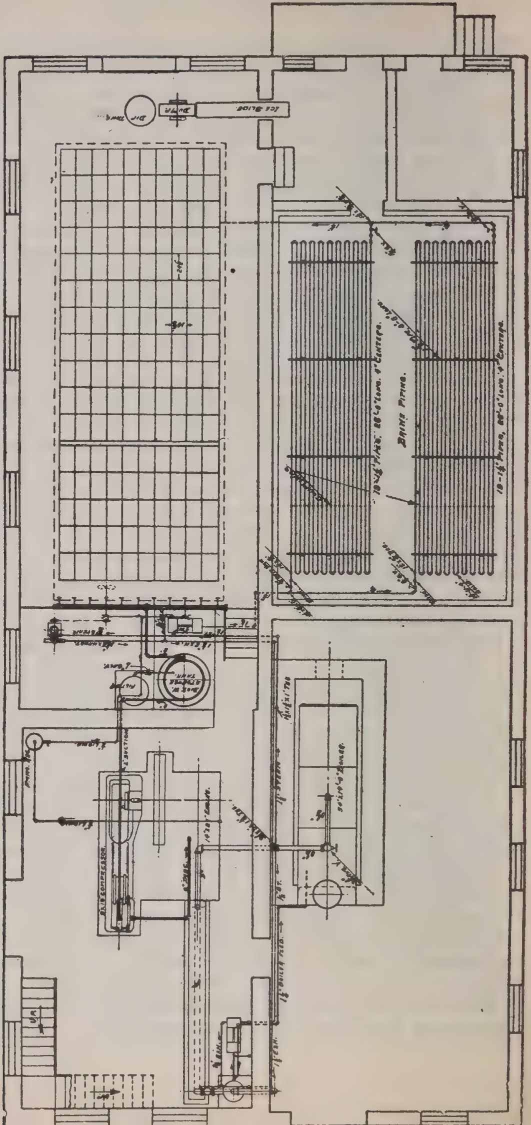
SECTION THRU ENGINE & TANK ROOMS

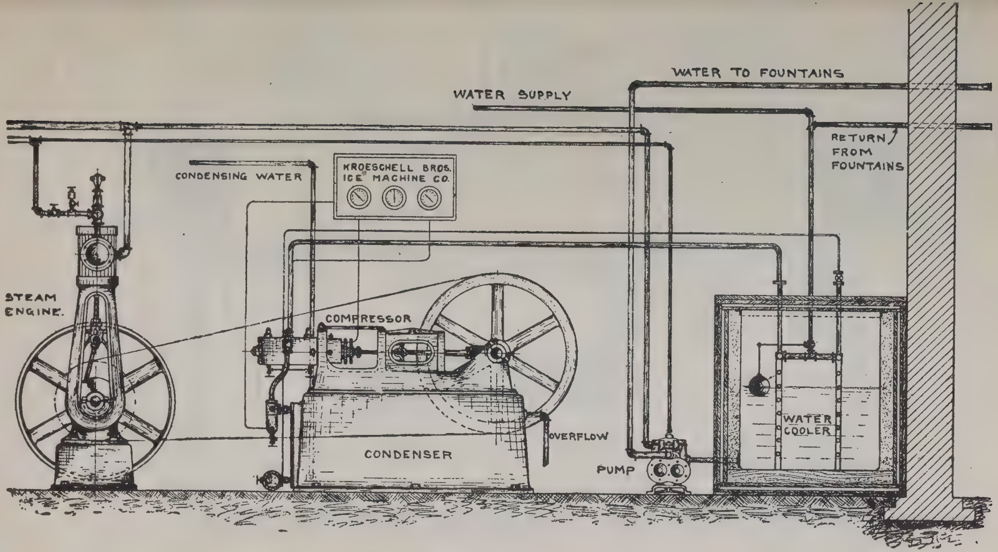
A Modern Ice Making Plant

Illustration A shows an elevation of a modern 10-ton ice making plant of brick construction. Reader will observe that the building to the left is an engine room—portion of the plant—same being two floors in height. The Triumph Ammonia Compressor has a 9″ x 18″ double acting cylinder and is driven by a slide valve engine, although in many instances a Corliss engine is used in a plant of this capacity, and a Corliss engine will be somewhat more economical in the use of steam. On the second floor of the engine room is located the ammonia condenser. On the roof is that portion of the distilling system aside of the exhaust steam separator, steam condenser and reboiler. To the right on the same floor with the engine and compressor, but in the adjoining room, is located a 50-horse power boiler which supplies steam to the plant. To the right of the illustration will be seen the ice making room, in which is located a ¼″ steel ice making tank containing one hundred and sixty 300-pound ice cans. These cans are lifted from the bath or brine by means of the traveling crane. The ice is thawed from the can by being immersed in the dip tank shown at the end of ice making tank in illustration B. After the ice is thawed from the can it is hoisted and delivered from the can by means of the ice dump placed adjacent to the dip tank. From the plan view in illustration B will be seen the ice storage room which is cooled by means of brine piping. A small duplex pump takes a small portion of the brine from the tank and circulates through the brine piping, which in turn enters the ice storage room at a temperature below freezing point. The cycle of operation is as follows: The ammonia in a gaseous form is pumped by means of the compressor in through an oil intercepter or oil trap, which is located near the ammonia condenser. This robs the gaseous ammonia of the oil used for lubricating the valves of the compressor. The ammonia is then delivered into the ammonia condenser, which condenses it into a liquid. The pressures from the discharge side of the compressor through the oil trap and ammonia condenser is from 150 to 200 pounds pressure, depending on the temperature of the water that flows over the ammonia condenser.

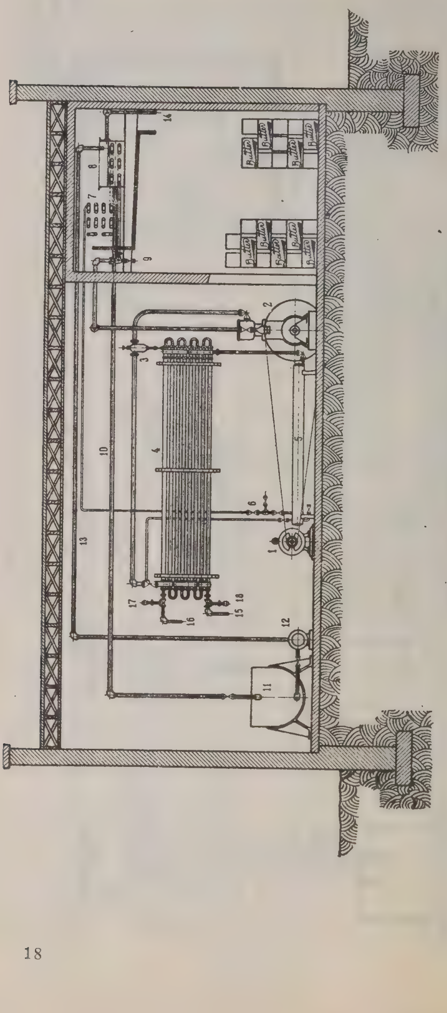
The liquor that has been condensed is deposited in a liquid receiver, which is shown in an upright position directly in front of the compressor and engine. From this receiver the liquid is conducted to the ice making tank coils, which coils are located between the various rows of ice cans. The ammonia is liberated from its high pressure, allowed to expand to a low pressure of about 15 pounds, and in so doing boils at a temperature of about zero Fahrenheit. This low temperature of the ammonia gas causes the brine to be reduced to a temperature of about 10 or 12 degrees above zero, and this low temperature likewise freezes the water in the can, requiring about 48 to 54 hours to freeze up a 300-pound block of ice.

The distilling system handles the exhaust steam after leaving the engine. This exhaust steam passes through a feed water heater shown at the left hand side of the engine room, thereby heating the incoming water that goes into the boiler. From the heater the exhaust steam at a pressure of 2 or 3 pounds passes up through an oil separator where the oil is extracted that has previously been used in lubricating the valves of the steam engine, thence to the steam condenser in which the steam is condensed to a liquid, the hot water then being conveyed through a 1″ galvanized pipe into the reboiler. A small live steam coil, located in this reboiler, causes the hot water to reboil. This process causes any oil left in the water to rise to the surface where a drain is provided for its removal. This hot water is then taken out of the bottom of the reboiler through a float tank, which keeps the water at a proper level in the reboiler and into the flat cooler. This flat cooler is composed of two sections of 1¼″ and 2″ galvanized pipes, the distilled water passing through the annular spaces between the pipes and the cold water passing through the 1¼″ pipe. The distilled water is then passed through a charcoal filter where any impurities or obnoxious odors are trapped. The water then passes through the storage tank where the water is cooled prior to entering the cans, by means of the return gas from the expanded coils going through a coil of pipe located in this cooler on its way back to the compressor.


Dip Tank
Ice Slide
Brine Piping.
10-1½" Pipes, 28'-0" Long, 4" Centers.
10-1½" Pipes, 28'-0" Long, 4" Centers.
Filter
2" Suction
Amm. Rec.
8x16 Compressor
14x20 Engine
1½" Boiler Feed


WATER TO FOUNTAINS
WATER SUPPLY
RETURN FROM FOUNTAINS
CONDENSING WATER
KROESCHELL BROS. ICE MACHINE CO.
STEAM ENGINE.
COMPRESSOR
OVERFLOW
CONDENSER
PUMP
WATER COOLER

Complete Outfit for Water Cooling



CREAMERY REFRIGERATING PLANT DIAGRAM

1 Electric Motor
2 Ammonia Compressor
3 Oil Trap
4 Ammonia Condenser
5 Liquid Receiver
6 Expansion Cock
7 Expansion Coils
8 Brine Tank
9 Oil Drain for Coils
10 Brine Supply to Cream Vat
11 Cream Vat
12 Brine Pump
13 Brine Return
14 Brine Overflow
15 Water Inlet
16 Water Outlet
17 Washout Inlet
18 Washout Outlet

Creamery Refrigerating Plant

The past few years have shown a wonderful awakening of interest in the subject of artificially cooling Dairy and Creamery Products on account of the many disadvantages possessed by the old manner of cooling by natural ice.

The progressive creamery and dairyman has not been slow to realize the vast superiority of the modern method of cooling because of the many sanitary features, simplicity, cleanliness and efficiency,—the artificial cooling doing away with the contaminating influences of natural ice which often being cut from filthy ponds, rivers and lakes, is a ready vehicle of disease from the time it leaves its place in the ice house until it is eventually dragged into the refrigerator, leaving behind it a long train of dirt and moisture. The only barrier that formerly stood in the way of cooling by machinery was the price, or initial cost, which, owing to the crude method of manufacture was rather high; it has, however, by the use of modern machinery and tools been reduced to a very reasonable basis, and the expense of maintenance and cost of operation has also been brought down to where this item becomes quite a saving in the cooling bill, when once the machinery is installed.

The Vilter Mfg. Co., who were among the pioneers in the Ice-making and Refrigerating industry and who have been responsible for many of the improvements that have taken place in that line of manufacture, have this class of machinery in operation with every line of trade where artificial refrigeration is required, such as with cold storage houses, hotels, restaurants, dairies, creameries and even private houses, etc.

There is a constantly growing demand for small ice-making and refrigerating machines all over the world, and particularly so in the creameries and dairies. That this demand must necessarily result in a very large volume of business and in the specialization of this branch of the industry by the established manufacturers of ice-making and refrigerating machines is a foregone conclusion.

We designed a perfect small and closed type Vertical Single Acting Ammonia Compressor and after making the requisite test have perfected such. This machine has received very favorable consideration by the prospective users of refrigeration in a small way, or for the production of a small quantity of ice daily. This machine has been placed on the market and a large number of them are now in daily operation in all parts of the United States and other countries.

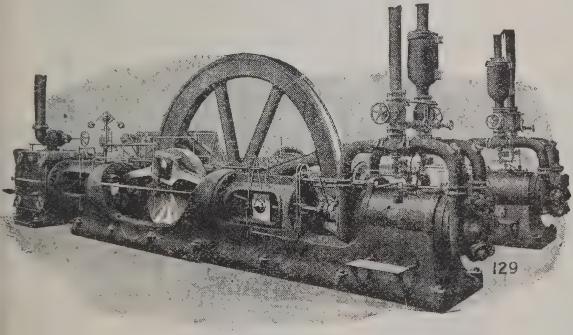
The machine, as may be seen from the illustration, is designed for operation from any source of power, the fly-wheel being faced for belt transmission from electric motor, gas or gasoline engines, separate steam engine or steam engine on the same bed plate, or from a line shaft or such power that is most economically available where the machine is installed.

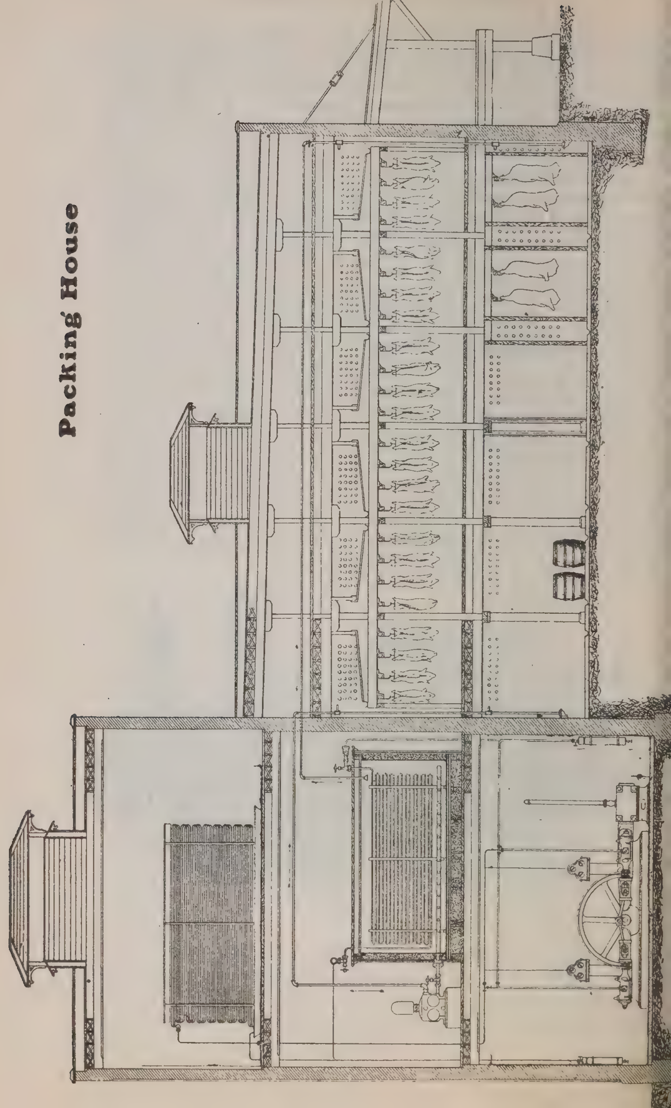
In designing this machine the company worked from the point of view of the ultimate purchaser and user, realizing that the average buyer would require, first, a machine of reasonable first cost; second, a machine of few parts and utmost simplicity; third, a machine that should be nearly automatic and practically entirely trouble-proof; and four, a machine of steady and durable construction, the last, of course, meaning the best of materials, skilled workmanship and a sufficient weight and strength to withstand the working strain at all speeds.

To improve upon the existing type of machinery and to reduce manufacturing costs at the same time could only be accomplished through skilled design permitting simplification and through large production, and it is entirely due to the recognition of these facts that this new and better small machine is now being produced and marketed in large numbers.

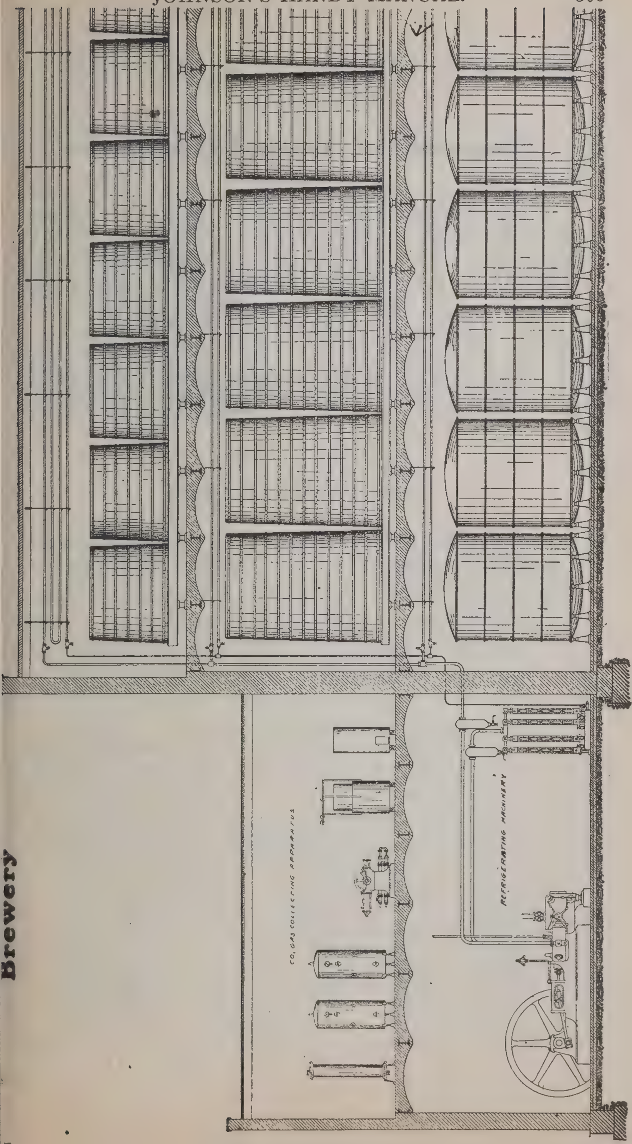
The process of simplification consisted in the elimination of every unnecessary extra part or joint requiring useless machine work for fittings and studs, nuts, bolts or cap screws for joining. The modern idea of newly construction has been employed just as far as it could be made applicable to this class of machinery, and in every instance of such application has added strength to the machine, giving it a better appearance and reduced the labor cost of construction.

To illustrate this: The complete base, two large crank-shaft bearings, the crank case and compressor supporting riser are cast in one integral casting, avoiding the several operations of machine facing and bolting these parts together. The compressor, compressor water jacket, flange inlet and outlet connection members form another single unit and save all work which would be necessary to fit the parts together, were they separately cast. The bolting together of the two mentioned units, and the placing of the crank case cover and cylinder head completes the non-moving structure of the entire machine proper. The crank-shaft bearings are so liberally proportioned that a straight, round steel crank shaft with single arm crank is used, instead of a double throw crank shaft with a troublesome bearing in the crank case cover,—another illustration of how simplicity has effected improvements without increasing cost. Pressed steel construction has been adopted for the compressor discharge valves, permitting a valve of larger area to be of light weight and eliminating all the complications of the valve stem and its driving mechanism. The piston has been simplified and is made gas-tight with simple snap-rings. The suction valve forms part of the piston and is not in the least complicated. In fact, the design of the entire machine is based upon the fundamental principle that simplicity is the main feature which proves the final worth of mechanical devices.





Packing House


CO2 GAS COLLECTING APPARATUS
REFRIGERATING MACHINERY

Brewery

Dimensions of Vertical Compressors

Capacity Tons	Diam. and Stroke	Flywheel D. and F.	Suction and Discharge	Length Conn. Rod	Width Stuff. Box	Diam. Shaft	Floor Space L. and W. and H.	Weight Crated	Power Required	
									Elec.	Gas Eng.
¾	3 x 3¾	16 x 3½	1	10	3	1¾	23x16x35	540	2	3
1½	4 x 5¼	24 x 5	1	12½	3⅝	1¾	32x24x65	1100	3	5
3	4 x 5	24 x 5	1	12¼	4½	2½	43x24x57	1700	5	7
5	4¾x 7	30 x 6½	1¼	17½	4⅞	3	52x30x66	2800	10	15
7	5⅝x 8	36 x 8½	1¼	17⅜	4 15/16	3½	52x36x70	3700	15	20
10	6½x10	48 x10½	1½	24⅞	5½	3⅝	61x48x90	4300	20	25
15	8 x12	72 x14	2	27¾	7	4 15/16	84x72x74	5900	30	35

Direct Expansion Piping.

The evaporation or expansion of the Carbonic Anhydride takes place in coils of extra heavy wrought-iron pipe. For brine tanks, water coolers, small refrigerators and rooms the pipes are welded into coils of continuous lengths and in large rooms the pipes are connected by flange unions.

Daily Capacity	Dimensions	
	A	B
5 tons	30 feet	56 feet
10 "	35 "	73 "
15 "	37 "	78 "
20 "	40 "	85 "
25 "	42 "	95 "
30 "	42 "	107 "
35 "	42 "	117 "
40 "	49 "	120 "
50 "	49 "	135 "
60 "	54 "	150 "
80 "	59 "	154 "
100 "	73 "	160 "

TIME REQUIRED FOR WATER TO FREEZE IN ICE CANS

Size of Cans, Inches	Weight of Cake, Pounds	Time to Freeze, Hours
6 x 12 x 24	50	20
8 x 18 x 32	100	36
8 x 16 x 40	150	36
11 x 22 x 32	200	55
11 x 22 x 44	300	60
11 x 22 x 57	400	60

NOTE—Temperature of bath 14° to 18° F. As a rule the higher the bath temperature, the slower the process of freezing, but the finer and clearer the ice.

Table Giving Number of Cubic Feet of Gas that must be Pumped per Minute at Different Condenser and Suction Pressures, to Produce One Ton of Refrigeration in Twenty-four Hours.

Temperature of Gas in Degrees F.	Corresponding Suction Pressure, Lbs. per sq. in.	Temperature of the Gas in Degrees F.								
		65°	70°	75°	80°	85°	90°	95°	100°	105°
		Corresponding Condenser Pressure (gauge), pounds per square inch.								
		103	115	127	139	153	168	184	200	218
	G. Pres.									
-27°	1	7.22	7.3	7.37	7.46	7.54	7.62	7.70	7.79	7.88
-20°	4	5.84	5.9	5.96	6.03	6.09	6.16	6.23	6.30	6.43
-15°	6	5.35	5.4	5.46	5.52	5.58	5.64	5.70	5.77	5.83
-10°	9	4.66	4.73	4.76	4.81	4.86	4.91	4.97	5.05	5.08
- 5°	13	4.09	4.12	4.17	4.21	4.25	4.30	4.35	4.40	4.44
0°	16	3.59	3.63	3.66	3.70	3.74	3.78	3.83	3.87	3.91
5°	20	3.20	3 24	3.27	3.30	3.34	3.38	3.41	3.45	3.49
10°	24	2.87	2.9	2.93	2.96	2.99	3.02	3.06	3 09	3.12
15°	28	2.59	2.61	2.65	2.68	2.71	2.73	2.76	2.80	2.82
20°	33	2.31	2.34	2 36	2.38	2.41	2.44	2.46	2.49	2.51
25°	39	2.06	2.08	2.10	2.12	2.15	2.17	2.20	2.22	2.24
30°	45	1.85	1.87	1.89	1.91	1.93	1.95	1.97	2.00	2.01
35°	51	1.70	1.72	1.74	1.76	1.77	1.79	1.81	1.83	1.85

STRENGTH OF AMMONIA LIQUORS

Percentage of Ammonia by Weight	Specific Gravity	Degrees Beaume. Water 10	Degrees Beaume Water 0
0	1.000	10.0	0.0
1	0.993	11.0	1.0
2	0.986	12.0	2.0
4	0.979	13.0	3.0
6	0.972	14.0	4.0
8	0.966	15.0	5.0
10	0.960	16.0	6.0
12	0.953	17.1	7.0
14	0.945	18.3	8.2
16	0.938	19.5	9.2
18	0.931	20.7	10.3
20	0.925	21.7	11.2
22	0.919	22.8	12.3
24	0.913	23.9	13.2
26	0.907	24.8	14.3
28	0.902	25.7	15.2
30	0.897	26.6	16.2
32	0.892	27.5	17.3
34	0.888	28.4	18.2
36	0.884	29.3	19.1
38	0.880	30.2	20.0

TABLE OF BRINE SOLUTION

(Chloride of Sodium—Common Salt)

Percentage of Salt by weight	Degrees on Salometer at 60 Degrees F.	Specific Gravity at 60 Degrees F.	Specific Heat	Weight of 1 Gallon	Pounds of Salt in 1 Gallon	Pounds of Water in 1 Gallon	Weight of 1 Cubic Foot	Pounds of Salt in 1 Cubic Foot	Pounds of Water in 1 Cubic Foot	Freezing Point Degrees F.
0	0	1.	1.	8.35	0.	8.35	62.4	0.	62.4	32.
1	4	1.007	0.992	8.4	0.084	8.316	62.8	0.628	62.172	31.8
5	20	1.037	0.96	8.65	0.432	8.218	64.7	3.237	61.465	25.4
10	40	1.073	0.892	8.95	0.895	8.055	66.95	6.695	60.253	18.6
15	60	1.115	0.855	9.3	1.395	7.905	69.57	10.435	59.134	12.2
20	80	1.150	0.829	9.6	1.92	7.68	71.76	14.352	57.408	6.86
25	100	1.191	0.783	9.94	2.485	7.455	74.26	18.565	55.695	1.00

CORRECTION FOR TEMPERATURE OF AQUA AMMONIA

The figures in top row indicate degrees Fahrenheit; those in the columns beneath give the strength of Ammonia at 60°

Degrees Beaume	60°	66°	67°	68°	72°	74°	76°	78°	81°	84°	88°	90°	92°	95°	96°	100°	102°	108°	109°
18	18	......	......	17¾	......	......	17½	......	......	17¼	......	......	17	......	......	16¾	......	16½	......
18¼	18¼	......	......	18	......	......	17¾	......	......	17½	......	......	17¼	......	......	17	......	16¾	......
18½	18½	......	......	18¼	......	......	18	......	......	17¾	......	......	17½	......	......	17¼	......	17	......
18¾	18¾	......	......	18½	......	......	18¼	......	......	18	......	......	17¾	......	......	17½	......	17¼	......
19	19	......	......	18¾	......	......	18½	......	......	18¼	......	......	18	......	......	17¾	......	17½	......
19¼	19¼	......	......	19	......	......	18¾	......	......	18½	......	......	18¼	......	......	18	......	17¾	......
19½	19½	......	......	19¼	......	......	19	......	......	18¾	......	......	18½	......	......	18¼	......	18	......
19¾	19¾	......	......	19½	......	......	19¼	......	......	19	......	......	18¾	......	......	18½	......	18¼	......
20	20	......	19¾	......	......	19½	......	......	19¼	......	19	......	......	18¾	......	......	18½	......	18¼
20¼	20¼	......	20	......	......	19¾	......	......	19½	......	19¼	......	......	19	......	......	18¾	......	18½
20½	20½	......	20¼	......	......	20	......	......	19	......	19½	......	......	19¼	......	......	19	......	18¾
20¾	20¾	......	20½	......	......	20¼	......	......	20½	......	19¾	......	......	19½	......	......	19¼	......	19
21	21	......	20¾	......	......	20½	......	......	20	......	20	......	......	19¾	......	......	19½	......	19¼
21¼	21¼	......	21	......	......	20¾	......	......	20¾	......	20¼	......	......	20	......	......	19¾	......	19½
21½	21½	......	21¼	......	......	21	......	......	20	......	20½	......	......	20¼	......	......	20	......	19¾
21¾	21¾	......	21½	......	......	21¼	......	......	21	......	20¾	......	......	20½	......	......	20¼	......	20
22	22	21¾	......	......	21½	......	......	21¼	......	21	......	20¾	......	......	20½	......	20¼	20	......
22¼	22¼	22	......	......	21¾	......	......	21½	......	21¼	......	21	......	......	20¾	......	20½	20¼	......
22½	22½	22¼	......	......	22	......	......	21¾	......	21½	......	21¼	......	......	21	......	20¾	20½	......
22¾	22¾	22½	......	......	22¼	......	......	22	......	21¾	......	21½	......	......	21¼	......	21	20¾	......
23	23	22¾	......	......	22½	......	......	22¼	......	22	......	21¾	......	......	21½	......	21¼	21	......
23¼	23¼	23	......	......	22¾	......	......	22½	......	22¼	......	22	......	......	21¾	......	21½	21¼	......
23½	23½	23¼	......	......	23	......	......	22¾	......	22½	......	22¼	......	......	22	......	21¾	22½	......

CORRECTION FOR TEMPERATURE OF AQUA AMMONIA—Continued

The figures in top row indicate degrees Fahrenheit: those in the columns beneath give the strength of Ammonia at 60°

Degrees Beaume	60°	64°	65°	68°	70°	72°	75°	76°	80°	84°	85°	88°	90°	92°	95°	96°	100°	104°	105°
23¾	23¾	.....	23½	.....	23¼	.....	23	.....	22¾	.....	22½	.....	22¼	.....	22	.....	21¾	.....	21½
24	24	.....	23¾	.....	23½	.....	23¼	.....	23	.....	22¾	.....	22½	.....	22¼	.....	22	.....	21¾
24¼	24¼	.....	24	.....	23¾	.....	23½	.....	23¼	.....	23	.....	22¾	.....	22½	.....	22¼	.....	22
24½	24½	.....	24¼	.....	24	.....	23¾	.....	33½	.....	23¼	.....	23	.....	22¾	.....	22½	.....	22¼
24¾	24¾	.....	24½	.....	24¼	.....	24	.....	23¾	.....	23½	.....	23¼	.....	23	.....	22¾	.....	22½
25	25	.....	24¾	.....	24½	.....	24¼	.....	24	.....	23¾	.....	23½	.....	23¼	.....	23	.....	22¾
25¼	25¼	.....	25	.....	24¾	.....	24½	.....	24¼	.....	24	.....	23¾	.....	23½	.....	23¼	.....	23
25½	25½	25¼	.....	25	.....	24¾	.....	24½	24¼	24	.....	23¾	.....	23½	.....	23¼	23	22¾	.....
25¾	25¾	25½	.....	25¼	.....	25	.....	24¾	24½	24¼	.....	24	.....	23¾	.....	23½	23¼	23	.....
26	26	25¾	.....	25½	.....	25¼	.....	25	24¾	24½	.....	24¼	.....	24	.....	23¾	23½	23¼	.....
26¼	26¼	26	.....	25¾	.....	25½	.....	25¼	25	24¾	.....	24½	.....	24¼	.....	24	23¾	23½	.....
26½	26½	26¼	.....	26	.....	25¾	.....	25½	25¼	25	.....	24¾	.....	24½	.....	24¼	24	23¾	.....
26¾	26¾	26½	.....	26¼	.....	26	.....	25¾	25½	25¼	.....	25	.....	24¾	.....	24½	24¼	24	.....
27	27	26¾	.....	26½	.....	26¼	.....	26	25¾	25½	.....	25¼	.....	25	.....	24¾	24½	24¼	.....
27¼	27¼	27	.....	26¾	.....	26½	.....	26¼	26	25¾	.....	25½	.....	25¼	.....	25	24¾	24½	.....
27½	27½	27¼	.....	27	.....	26¾	.....	26½	26¼	26	.....	25¾	.....	25½	.....	25¼	25	24¾	.....
27¾	27¾	27½	.....	27¼	.....	27	.....	26¾	26½	26¼	.....	26	.....	25¾	.....	25½	25¼	25	.....
28	28	27¾	.....	27½	.....	27¼	.....	27	26¾	26½	.....	26¼	.....	26	.....	25¾	25½	25¼	.....

The specific gravity of Aqua Ammonia changes with the temperature at which it is measured with the hydrometer. The readings are too high if the temperature of the Ammonia is over 60° F., and too low if under. In order to ascertain the exact strength of Ammonia at 60° F. make corrections for temperature in accordance with the table above, thus: 26½° Ammonia measured at a temperature of 80° F., is equal to 25¼° Ammonia at a temperature of 60° F.

TABLE OF CHLORIDE OF CALCIUM SOLUTION

Specific Gravity at 64 Degrees F.	Degree Beaume at 64 Degrees F.	Degree Salometer at 64 Degrees F.	Per Cent of $CaCl_2$	Freezing Point in Degrees F.	Ammonia Gauge Pressure Pounds per Square Inch.
1.007	1	4	0.943	+31.20	46
1.014	2	8	1.886	+30.40	45
1.021	3	12	2.829	+29.60	44
1.028	4	16	3.772	+28.80	43
1.035	5	20	4.715	+28.00	42
1.043	6	24	5.658	+26.89	41
1.050	7	28	6.601	+25.78	40
1.058	8	32	7.544	+24.67	38
1.065	9	36	8.487	+23.56	37
1.073	10	40	9.430	+22.09	35.5
1.081	11	44	10.373	+20.62	34
1.089	12	48	11.316	+19.14	32.5
1.097	13	52	12.259	+17.67	30.5
1.105	14	56	13.202	+15.75	29
1.114	15	60	14.145	+13.82	27
1.112	16	64	15.088	+11.89	25
1.131	17	68	16.031	+ 9.96	23.5
1.140	18	72	16.974	+ 7.68	21.5
1.149	19	76	17.917	+ 5.40	20
1.158	20	80	18.860	+ 3.12	18
1.167	21	84	19.803	— 0.84	15
1.176	22	88	20.746	— 4.44	12.5
1.186	23	92	21.689	— 8.03	10.5
1.196	24	96	22.632	—11.63	8
1.205	25	100	23.575	—15.23	6
1.215	26	104	24.518	—19.56	4
1.225	27	108	25.461	—24.43	1.5
1.236	28	112	26.404	—29.29	1 in. vacuum
1.246	29	116	27.347	—35.30	5 " vacuum
1.257	30	120	28.290	—41.32	8.5 " vacuum
1.268	31	...	29.233	—47.66	12 " vacuum
1.279	32	...	30.176	—54.00	15 " vacuum
1.290	33	...	31.119	—44.32	10 " vacuum
1.302	34	...	32.062	—34.66	4 " vacuum
1.313	35	...	33.	—25.00	1.5 pounds

HORSE POWER REQUIRED TO COMPRESS ONE CUBIT FOOT OF AMMONIA PER MINUTE

Condenser Pressure and Temperature

p	103	115	127	139	153	168	184	200	218
t	65°	70°	75°	80°	85°	90°	95°	100°	105°
— 20°	.1809	.1916	.2022	.2128	.2235	.2342	.2448	.2554	.2661
— 15°	.1864	.1980	.2097	.2214	.2330	.2447	.2563	.2679	.2796
— 10°	.1937	.2067	.2196	.2325	.2454	.2583	.2712	.2842	.2971
— 5°	.2001	.2144	.2287	.2430	.2573	.2716	.2859	.3002	.3145
0°	.2048	.2206	.2363	.2521	.2679	.2836	.2994	.3151	.3309
5°	.2083	.2257	.2430	.2604	.2778	.2952	.3125	.3299	.3473
10°	.2096	.2286	.2477	.2667	.2858	.3048	.3239	.3429	.3620
15°	.2089	.2298	.2506	.2715	.2924	.3133	.3342	.3551	.3760
20°	.2054	.2282	.2510	.2738	.2966	.3195	.3423	.3651	.3879
25°	.1992	.2240	.2489	.2738	.2987	.3226	.3485	.3734	.3983
30°	.1897	.2169	.2440	.2711	.2982	.3253	.3524	.3795	.4066
35°	.1768	.2062	.2357	.2651	.2946	.3241	.3535	.3830	.4124

NOTE—These figures do not allow for friction.

COMPARISON OF THERMOMETERS

Cent.	Reau.	Fahr.	Cent.	Reau.	Fahr.	Cent.	Reau.	Fahr.
—40	—32.0	—40.0	21	16.8	69.8	62	49.6	143.6
—38	—30.4	—36.4	22	17.6	71.6	63	50.4	145.4
—36	—28.8	—32.8	23	18.4	73.4	64	51.2	147.2
—34	—27.2	—29.2	24	19.2	75.2	65	52.0	149.0
—32	—25.6	—25.6	25	20.0	77.0	66	52.8	150.8
—30	—24.0	—22.0	26	20.8	78.8	67	53.6	152.6
—28	—22.4	—18.4	27	21.6	80.6	68	54.4	154.4
—26	—20.8	—14.8	28	22.4	82.4	69	55.2	156.2
—24	—19.2	—11.2	29	23.2	84.2	70	56.0	158.0
—22	—17.6	— 7.6	30	24.0	86.0	71	56.8	159.8
—20	—16.0	— 4.0	31	24.8	87.8	72	57.6	161.6
—18	—14.4	— 0.4	32	25.6	89.6	73	58.4	163.4
—16	—12.8	+ 3.2	33	26.4	91.4	74	59.2	165.2
—14	—11.2	6.8	34	27.2	93.2	75	60.0	167.0
—12	— 9.6	10.4	35	28.0	95.0	76	60.8	168.8
—10	— 8.0	14.0	36	28.8	96.8	77	61.6	170.6
— 8	— 6.4	17.6	37	29.6	98.6	78	62.4	172.4
— 6	— 4.8	21.2	38	30.4	100.4	79	63.2	174.2
— 4	— 3.2	24.8	39	31.2	102.2	80	64.0	176.0
— 2	— 1.6	28.4	40	32.0	104.0	81	64.8	177.8
0	0.0	32.0	41	32.8	105.8	82	65.6	179.6
+ 1	+ 0.8	33.8	42	33.6	107.6	83	66.4	181.4
2	1.6	35.6	43	34.4	109.4	84	67.2	183.2
3	2.4	37.4	44	35.2	111.2	85	68.0	185.0
4	3.2	39.2	45	36.0	113.0	86	68.8	186.8
5	4.0	41.0	46	36.8	114.8	87	69.6	188.6
6	4.8	42.8	47	37.6	116.6	88	70.4	190.4
7	5.6	44.6	48	38.4	118.4	89	71.2	192.2
8	6.4	46.4	49	39.2	120.2	90	72.0	194.0
9	7.2	48.2	50	40.0	122.0	91	72.8	195.8
10	8.0	50.0	51	40.8	123.8	92	73.6	197.6
11	8.8	51.8	52	41.6	125.6	93	74.4	199.4
12	9.6	53.6	53	42.4	127.4	94	75.2	201.2
13	10.4	55.5	54	43.2	129.2	95	76.0	203.0
14	11.2	57.2	55	44.0	131.0	96	76.8	204.8
15	12.0	59.0	56	44.8	132.8	97	77.6	206.6
16	12.8	60.8	57	45.6	134.6	98	78.4	208.4
17	13.6	62.6	58	46.4	136.4	99	79.2	210.2
18	14.4	64.4	59	47.2	138.2	100	80.0	212.0
19	15.2	66.2	60	48.0	140.0			
20	16.0	68.0	61	48.8	141.8			

Freezing point on Fahrenheit scale is +32 degrees; boiling point, 212 degrees.

Freezing point on Centigrade scale is +0 degrees; boiling point, 100 degrees.

Freezing point on Reaumur scale is +0 degrees; boiling point, 80 degrees.

Of water at sea level at normal barometer pressure (29.9 inch).

The "absolute zero" of temperature denotes that condition of matter at which heat ceases to exist At this point a body would be wholly deprived of heat and a gas would exert no pressure.

The absolute zero on the Fahrenheit scale is about 461 degrees below zero.

The absolute zero on the Centigrade scale is about 274 degrees below zero.

The absolute zero on the Reaumur scale is about 219 degrees below zero.

An English unit of heat (B. T. U.) is the quantity required to raise one pound of Water one degree Fahrenheit. A metric unit of heat or metric caloric (M. C.) is the quantity of heat required to raise one litre of water one degree centigrade.

GENERAL DIMENSIONS IN FEET FOR ICE MAKING PLANTS

Capacity Tons Ice	A	B	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	T
2	47	28	17	10	18	10	10	28	12	8	18	16	20	6	9	16	5	12	10
5	48	42	17	10	32	10	10	42	13	8	32	16	20	6	9	16	5	12	10
8	61	34	19	12	24	12	10	34	22	8	24	16	20	6	10	16	5	12	10
10	72	34	21	15	24	15	10	34	26	10	24	16	20	6	10	16	5	12	10
12	72	38	21	15	28	15	10	38	26	10	28	16	20	6	10	16	5	12	10
15	78	44	24	18	34	18	10	44	26	10	34	16	20	6	12	20	5	12	10
18	80	50	24	18	40	18	10	50	26	12	40	16	20	6	12	20	5	12	10
20	87	46	25	18	36	18	10	46	32	12	36	16	22	6	12	20	5	12	10
25	89	54	25	20	44	20	10	54	32	12	44	16	22	6	12	20	5	12	10
30	92	62	25	20	50	20	12	62	32	15	52	16	22	6	12	20	5	12	10
35	93	70	26	20	58	20	12	70	32	15	60	16	22	6	12	22	5	12	10
40	93	79	26	20	67	20	12	79	32	15	69	16	22	6	12	22	5	12	10
50	114	54	35	25	39	25	15	54	64	20	44	20	22	6	12	24	5	12	10
60	145	62	36	25	47	25	15	62	64	20	52	20	25	6	12	24	5	12	10
75	160	79	46	30	64	30	15	79	64	20	69	20	25	6	12	27	5	12	10
100	173	95	54	30	80	30	15	95	64	25	85	20	25	6	12	30	5	12	10
150	247	95	76	40	80	30	15	95	96	35	85	20	25	6	12	30	5	12	10
200	333	95	100	40	80	30	15	95	128	45	85	20	25	6	12	30	5	12	10

HORSE POWER REQUIRED TO PRODUCE ONE TON OF REFRIGERATION

Condenser Pressure and Temperature

Refrigerator Pressure and Temp.

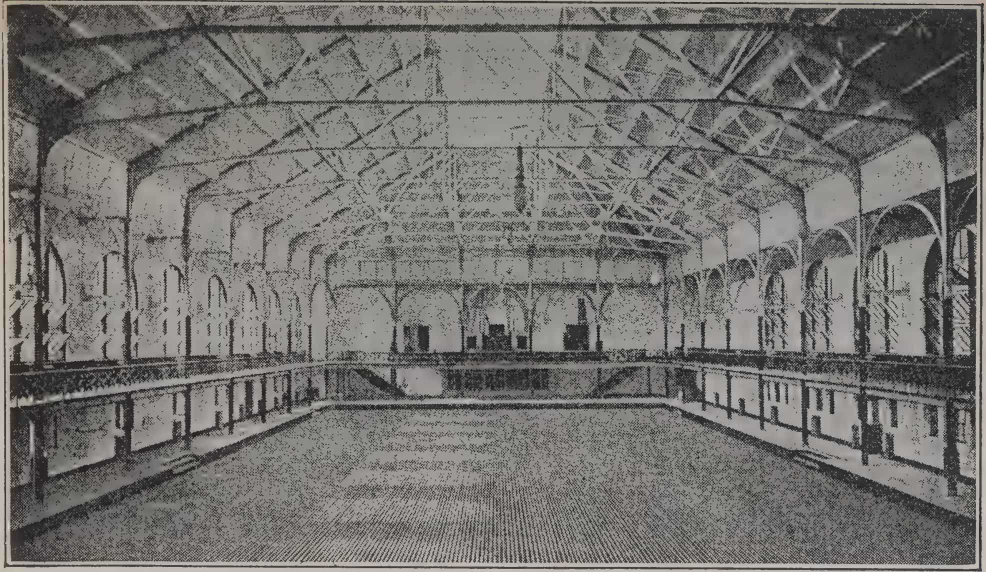
	p	103	115	127	139	153	168	184	200	218
p	t	65°	70°	75°	80°	85°	90°	95°	100°	105°
4	— 20°	1.0584	1.1304	1.2051	1.2832	1.3611	1.4427	1.5251	1.6090	1.6910
6	— 15°	.9972	1. 692	1.1450	1.2221	1.3001	1.4101	1.4609	1.5458	1.7300
9	— 10°	.9026	.9777	1.0453	1.1183	1.1926	1.2602	1.3471	1.4352	1.5093
13	— 5°	.8184	.8833	.9537	1.0230	1.0935	1.1679	1.2437	1.3209	1.3964
16	0°	.7352	.8008	.8648	.9328	1.0019	1.0718	1.1467	1.2194	1.2547
20	5°	.6665	.7312	.7946	.8593	.9278	.9978	1.0656	1.1381	1.2121
24	10°	.5915	.6629	.7257	.7894	.8545	.9205	.9911	1.0595	1.1294
28	15°	.5410	.5998	.6641	.7276	.7924	.8553	.9224	.9943	1.0603
33	20°	.4745	.5340	.5923	.6716	.7148	.7796	.8420	.9031	.9736
39	25°	.4103	.4659	.5227	.5804	.5992	.7022	.7667	.8289	.8922
45	30°	.3509	.4056	.4612	.5178	.5755	.6353	.6944	.7590	.8172
51	35°	.3005	.3546	.4101	.4666	.5214	.5804	.6398	.7009	.7629

NOTE—The figures in this table represent the minimum theoretical amount. In practice they must be increased about 50 per cent.

St. Nicholas Skating Rink, New York City

Artificial Ice-Skating Rinks

Artificial skating rinks should be in connection with cold storage or ice making plants. This makes a fine investment the year around. On all sides Delavergne Machine Co. of New York has the far been the most successful on the biggest skating rinks in the United States and has quite a number in operation all over this country and Canada. Coils in the rink floor are usually made of inch and quarter



Floor of St. Nicholas Skating Rink, showing pipes before flooding pipe. They run either way, lengthwise or crosswise of the rink floor. In this one rink the coils are shown running lengthwise. In either case inlet and outlet headers are provided which are simply manifolds with a connection for each inch and a quarter pipe. Each coil is usually provided with inlet valve and outlet valve so that each can be cut off from the rest if necessary.

For cooling the brine, one of two methods is generally employed. In one case there is provided a large steel tank in which direct expansion ammonia coils are submerged in the brine, similar to the freezing tank of an ice plant. The other arrangements consists of the use of a brine cooler of the shell and tube type which resembles very much a horizontal tubular steam boiler. The brine passes through the tubes, making several passes, while the ammonia is on the inside of the shell and evaporates there, producing the cooling effect. In connection with this latter type of cooler, it is necessary to use a small tank known as a balancing or compensating tank, since the volume of brine contained in the cooler is rather small, and it is necessary to have this tank in order to provide for a larger amount.

For circulating the brine through the coils, usually a centrifugal pump is used when electric power is used for driving the plant. The electric motor is direct connected to the pump, and in connection with the shell cooler, the section of the pump is connected to the balance of the tank and the discharge leads to the cooler and from there to the coils. In case the plant is steam-driven, an ordinary direct connected Duplex steam pump could be used, although this type is very economical in the use of steam.

Freezing System.

There are two standard systems of cooling and freezing. We refer to the brine system and the direct expansion system. The direct expansion system provides for the direct expansion of ammonia in pipes whch are located directly in the rooms, chambers, tanks or whatever must be refrigerated. With the brine system, the ammonia is first expanded to cool a strong solution of salt or calcium brine which is circulated in the various rooms or chambers or tanks.

In the first system there is only one medium, while in the second system there are two mediums. This means an additional step, which reduces the economy. Therefore, the direct expansion system affords better economy.

In skating rinks, however, the use of the direct expansion system would be entirely impractical. The reason lies in the absolute necessity of freezing a smooth and even surface. On account of the length of the cooling coils which must be used for freezing such a surface, it would be impossible to regulate the direct expansion of ammonia in any manner to give good results.

Our Experience

The first artificial ice-skating rink in the United States was erected in New York City about twenty years ago. We refer to the well-known St. Nicholas Skating Rink, which has been in constant operation since that time.

With no other rinks to copy from, the engineers were compelled to make original designs in building the St. Nicholas Rink. The success of the plant was quite remarkable and only one difficulty was encountered after the rink started in operation.

It was found that considerable snow accumulated on the surface after each session, and to remove it, a mechanical scraper was experimented with, but proved to be impractical. After a short time, the trouble was overcome by removing the snow with artificial hand scrapers or a planer drawn by a donkey.

After the snow is removed, the surface is flooded with a thin film of water and then refrozen for the next session.

Circulation

The brine circulating system is the most important consideration in the mechanical equipment of a successful rink. It is necessary that the same temperature should exist throughout the entire freezing floor.

As the brine must travel through a considerable length of pipe and will naturally increase in temperature in its passage, it is evident that special steps must be taken to maintain the same temperatures at every point.

After the building of the first skating rink, it was though by some engineers that the amount of surface could be cut down and an attempt was made in one or two rinks to achieve the same results with 30 or 40 per cent less surface. The experiments were not successful and much trouble was experienced in maintaining a good skating surface.

The skating rinks built by us have very large cooling surfaces and large distributing mains, with a full complement of valves. The brine circulation is such that an even temperature is carried throughout and a perfectly smooth even skating surface is guaranteed.

Owing to the importance of a constant and rapid circulation, two large brine pumps are furnished to provide a spare unit.

Facts About Skating Rinks

Standard dimensions of floor surface for hockey games: 200 ft. by 85 ft.

Skating Rinks

Skating rinks require a plant of one ton of refrigerating capacity per 160 square feet of rink surface. One inch brine coils laid on bottom of pan are usually placed at 3″ centers and ice is frozen 3″ thick. After ice is frozen 450 B. T. U. per square yard will furnish a new sprinkled surface in about two hours. A rink will accommodate one person—per seventeen square feet.

Approximate number of persons which can skate on rink of standard size at one time: From 500 to 600.

Usual admission charge for skating: 25 to 50 cents per session.

Usual admission charge during hockey matches: Standing room, 50c. to $1.00; seats, 75c. to $2.00; box seats, $1.50 to $3.00, depending upon size of city and representation of the hockey teams playing.

Usual period of skating session: From October 1st to April 1st.

Usual number of skating sessions per day: Three —First session from 10 A. M. to 12:30 P. M.; Second session from 2:30 to 5 P. M.; Third session from 8 to 10:30 P. M.

Standard system of freezing floor surface: Brine circulation.

Approximate total refrigerating capacity of machines necessary for standard skating rinks: 100 tons every 24 hours, preferably in two units of 50 tons each.

Approximate ice-making capacity of same machines: 50 tons every 24 hours.

Approximate dimensions of building: 250 ft. long by 150 ft. wide or equivalent.

Approximate size of arena room: 225 ft. by 125 ft.

Approximate size of engine room: 40 ft. by 40 ft.

Approximate size of 50-ton freezing tank room: 50 ft. by 100 ft.

Operating force, engine room: 1 Chief Engineer, 2 Assistant Engineers, 2 Firemen (if boilers are used).

Office force: 1 Manager, 1 Bookeeper.

Attendants (approximate): 1 Ticket Seller, 1 Ticket Collector, 2 men to distribute skates, 1 maid, 1 coat room boy, 2 or 3 instructors, 3 or 4 attendants to put skates on, suitable band of music, 2 or 3 cleaners.

Floor Surface

The standard size of skating rinks for hockey games is now understood to be about 200 feet in length and about 85 feet in width. Some of the surfaces are slightly smaller, but these dimensions are recommended. For rough calculations, it can be assumed that for comfortable skating, about 30 square feet should be allowed for each person.

In other words, if a rink has 18,000 square feet, it will accomodate about 600 people at one time and not be over-crowded. The attendance may be larger than this precise number because there will always be a certain percentage coming, going and resting.

Machinery Equipment

The most practical arrangement of the refrigerating plant is to have two units. Both machines must be operated when freezing the surface and then one machine is usually sufficient to maintain it. Two machines, each of a refrigerating capacity of 50 tons every 24 hours are ample for taking care of the standard skating rink, the dimensions of which have already been given.

These two machines would also be capable of operating an ice-making plant of 50 tons daily capacity when the skating surface is not required. Such a plant is a good commercial size and can be operated with profit in any city where a skating rink might be located to advantage.

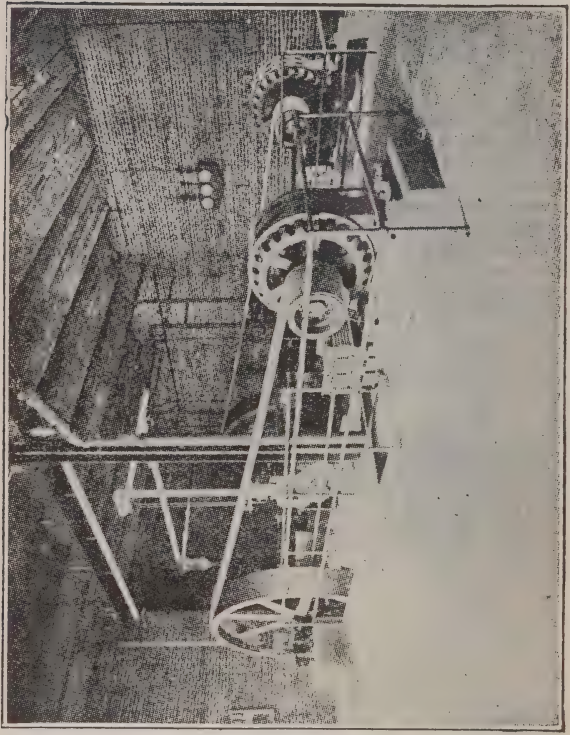
If only one machine is used, it can be of 75 tons refrigerating capacity, as this size would be sufficient to freeze the surface, although it would require a longer period to do the work than two 50-ton machines.

Two machines are surely the better layout, since they not only make it possible to shut down one unit when the surface is frozen, but also provide ample capacity to freeze the surface quickly and to manufacture 50 tons of ice in the summer months. Moreover, two units are always an advantage in case of accidents.

There may be situations where rinks of a smaller size than the standard surface would be practical, but it is doubtful if the surface could be any less than 13,000 or 14,000 square feet and offer any pleasure to skaters. It is essential to have about 150 feet in length and 80 or 90 feet in width, in order that the patrons will have room to skate without too many turns.

SURFACE					
Length	Width	Total Sq. feet	No. of Machines	Total Refrigerating Capacity per 24 hours	Estimated first cost complete mechanical equipment
100	50	5000	1	30 tons	$15,000.
100	80	8000	1	50 "	21,000.
150	80	12000	2	70 "	30,000.
200	80	16000	2	100 "	37,500.
250	100	25000	2	140 "	51,000.
300	100	30000	2	160 "	60,000.

Costs are based on ordinary steam driven plants including boiler. Motor drive will be found advantageous in some localities. Oil engines are especially suited to operate the machinery because the operation is not continuous and one machine in the larger plants is often shut down. The economy of this type of prime mover is emphasized under such conditions, as there are no standby losses and the moderate service reduces repair expense to a minimum. A very unusual arrangement can be found in the skating rink in Vancouver, B. C. Instead of large distributing headers, the brine is supplied to the circulating pipes from a long narrow tank located at one end at a height above the floor. The tank is just as long as the floor is wide and each floor pipe is connected up to the tank. The cold brine is not pumped through the coils, but flows by gravity from the supply tank. No particular advantage is found with this method and the layout proved more expensive than the regular design.



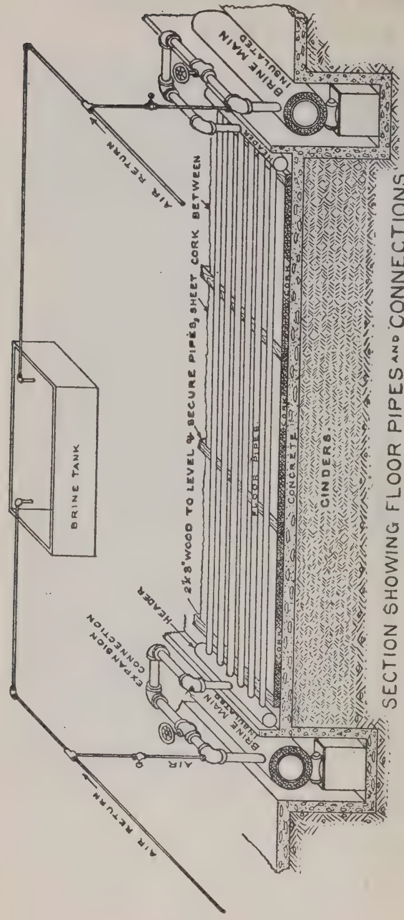
Engine Room, St. Nicholas Skating Rink, New York City; two motor-driven "De La Vergne" Machines

M. J. Palson's Patent Construction of Ice Rink Floors

The construction of this floor is plainly shown in the illustration on the following page, but a short explanation will not be out of place. The construction of the floor is as follows: After excavation to the required depth is done a thick cinder fill is deposited which must be well soaked with water and tamped down or rolled down solid. On top of this is placed a concrete floor with a cork insulation on top of this. Now comes the Palson patent way of building the balance of the floor, which is as follows: The floor pipes are placed directly on top of the cork insulation and are covered with a composition of concrete with iron turnings which extend an inch or so above the top of the pipes. From ⅜ inch to ½ inch is all the water that is required to be filled in and frozen. The old fashioned constructed rink has the freezing pipes about an inch above the insulated concrete floor. This space as well as that occupied by the pipe and an inch or more above must be filled with water and converted into ice. It follows, therefore, that it takes about ten times as long to freeze skating ice on the old fashioned floor, while it takes only eight hours to do it the new way.

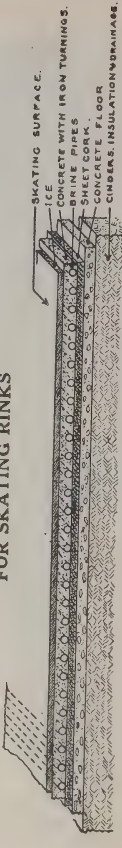
In order to remove the ice from the floor of the old fashioned rink every bit of this ice must be thawed and converted into water. With the new style of floor we warm the brine slightly, just enough to loosen the ice and enable the operator to strip off this thin ice coating and shovel it into a truck which is backed in on the floor for this purpose. By this means you can clear a floor of ice in five hours and thoroughly dry it in less time than that.

As it is a small task to remove the ice and dry the floor and only takes eight hours to freeze a new fill of water, it shows the flexibility of the uses to which buildings equipped with the Palson patent can be used. With almost lightning rapidity and at comparatively small expense the floor can be changed from an ice floor to a floor for dances or public gatherings. One night you can have a


AIR RETURN
BRINE MAIN INSULATED
HEADER
2½x3" WOOD TO LEVEL & SECURE PIPES, SHEET CORK BETWEEN
BRINE TANK
FLOOR PIPES
CORK
CONCRETE
CINDERS.
HEADER
EXPANSION CONNECTION
BRINE MAIN INSULATED
AIR
AIR RETURN

SECTION SHOWING FLOOR PIPES AND CONNECTIONS

FOR SKATING RINKS


SKATING SURFACE.
ICE
CONCRETE WITH IRON TURNINGS.
BRINE PIPES
SHEET CORK.
CONCRETE FLOOR
CINDERS, INSULATION & DRAINAGE.

SECTION ACROSS PIPES.

hockey match with public skating. The following night a boxing match, dance, or public meeting can be held. This could not be done with the ordinary style of floor. The smoothness and finish of the floor depends, of course, on the amount of work put in troweling it down. The surface can be waxed if necessary. It has, I believe, been found quite practicable to dance on a concrete floor without any wooden covering, but as a rule a wooden floor is laid down. For a public gathering there is no need of laying a wooden floor when the Palson system is used.

The public as a whole tire of the sameness, even in amusements. It is therefore perfectly plain that a skating rink floor that can be converted into any other use at a few hours notice is the thing to have.

Now to a few good points about the metallic mixture which encloses the pipes entirely in this new system. The transmission of heat or cold is accomplished many times more quickly and more evenly than if plain cement were used. The metallic contacts carry the heat from the water to the brine with astonishing rapidity. The brine pipes being embedded in the metallic mixture and thoroughly covered will last pretty nearly for ever, as it is a well known fact that iron or steel will not corrode or rust.

In the old style of construction the pipes used to be removed in the spring and replaced in the fall at a great expense of labor and loss of materials. This is entirely done away with in the new system.

Many skating rink floors, as formerly constructed, gave a great deal of trouble through air pockets in various parts in the brine piping in the floor. This left a lot of watery spots which were both disagreeable and if deep enough, dangerous. With the Palson automatic air eliminating system this never happens. Every inch of the floor is at all times perfect.

This system can be applied to skating rinks already erected.

Tonnage and Piping Tables

Cu. Ft. Space to 1 Ft. of Pipe

Cubic Space in Box or Room	Cubic Foot per Ton Ref.	Temperature 40°F					
		Direct Exp.			Brine †		
		1-in.	1¼-in.	2-in.	1-in.	1¼-in.	2-in.
12	150	3.	5.		2.5	4.	
20	185	3.1	5.1		2.6	4.1	
50	225	3.2	5.2		2.7	4.2	
100	300	3.4	5.5		2.8	4.4	
250	500		6.3			4.8	
500	850		7.5			5.6	
1,000	1200		8.7			6.4	9.5
3,000	1600		10.			7.3	11.
5,000	2300		12.	18.		9.	14.
10,000	3000		15.	22.		11.	16.
20,000	3700		18.	26.		12.	18.
40,000	4500		20.	30.		14.	21.
70,000	5800		25.	37.		17.	25.
100,000	7200		30.	45.		20.	30.

Cubic Space in Box or Room	Cubic Foot per Ton Ref.	Temperature 20°F					
		Direct Exp.			Brine ‡		
		1-in.	1¼-in.	2-in.	1-in.	1¼-in.	2-in.
12	113	1.6	2.2		1.4	2.	
20	137	1.7	2.3		1.4	2.	
50	160	1.8	2.4		1.5	2.1	
100	205	2.	2.6		1.6	2.2	
250	348		2.8			2.4	
500	580		3.2			2.7	
1,000	820		3.8	5.5		3.	4.
3,000	1100		4.5	6.5		3.4	4.5
5,000	1600		6.	8.		4.	5.5
10,000	2100		7.	10.		4.7	6.5
20,000	2600		8.	12.		5.5	7.5
40,000	3200		9.	14.		6.5	8.5
70,000	4000		11.	17.		7.5	10.
100,000	4900		14.	20.		9.	12.

Mean Temp. Ammonia Expansion 0°F.
" " Brine in Coils *5°, ‡10°F. & †15°.

Tables based on continuous operation 24 hours per day. If Ammo. is expanded half the time use equal length of pipe in brine tank and double the tonnage.

Tonnage and Piping Tables

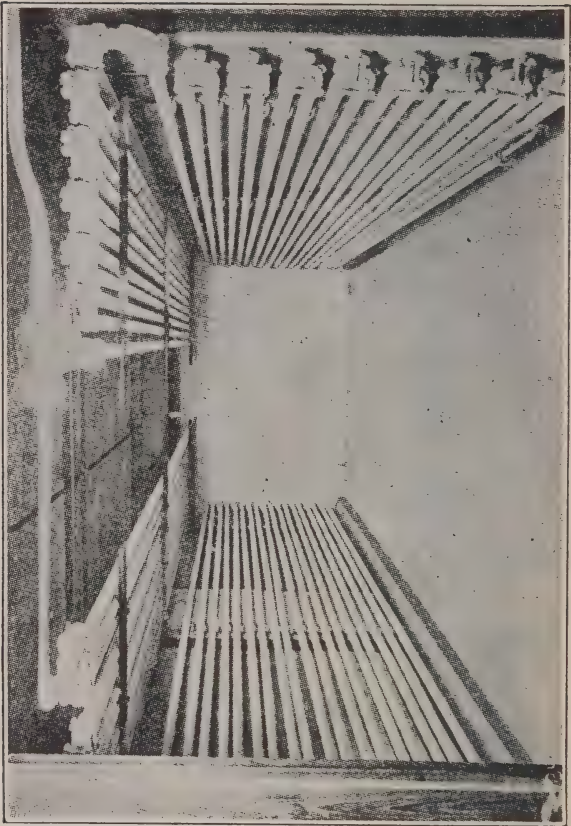
Cu. Ft. Space to 1 Ft. of Pipe

Cubic Space in Box or Room	Cubic Foot per Ton Ref.	Temperature 30°F					
		Direct Exp.			Brine †		
		1-in.	1¼-in.	2-in.	1-in.	1¼-in.	2-in.
12	130	2.3	3.5		2.	2.8	
20	159	2.4	3.6		2.	2.9	
50	200	2.5	3.7		2.1	3.	
100	260	2.7	3.9		2.2	3.1	
250	430		4.5			3.4	
500	710		5.4			4.	
1,000	1000		6.5			4.5	7.
3,000	1300		7.5	10.		5.	8.
5,000	1900		9.	12.		6.	9.
10,000	2600		11.	15.		7.	11.
20,000	3100		13.	17.		8.	12.
40,000	3700		15.	20.		10.	14.
70,000	4800		18.	24.		12.	17.
100,000	6000		20.	28.		14.	20.

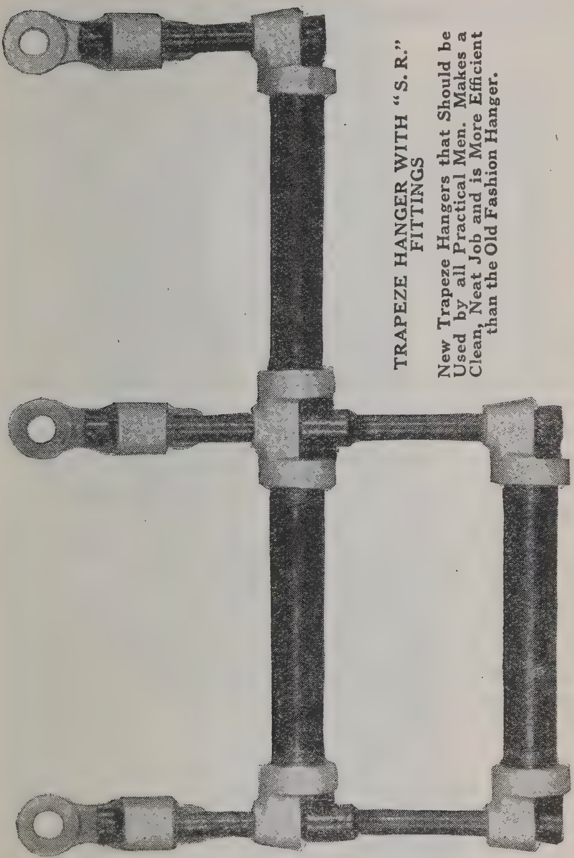
Cubic Space in Box or Room	Cubic Foot per Ton Ref.	Temperature 10°F					
		Direct Exp.			Brine *		
		1-in.	1¼-in.	2-in.	1-in.	1¼-in.	2-in.
12	93	1.	1.2		.6	1.1	
20	112	1.	1.2		.6	1.1	
50	130	1.1	1.2		.6	1.1	
100	168	1.2	1.3		.6	1.2	
250	280		1.4			1.3	
500	470		1.6	2.5		1.5	
1,000	650		2.2	3.		1.7	2.3
3,000	840		2.5	3.6		1.9	2.6
5,000	1140		3.2	4.6		2.2	3.3
10,000	1600		4.	5.7		2.6	4.
20,000	2100		4.8	6.8		3.	4.7
40,000	2600		5.5	8.		3.5	5.5
70,000	3100		6.5	10.		4.2	6.7
100,000	3800		8.	12.		5.	8.

Mean Temp. Ammonia Expansion 0°F.
" " Brine in Coils *5°, ‡10°F. & †15°

Tables based on continuous operation 24 hours per day. If Ammo. is expanded half the time use equal length of pipe in brine tank and double the tonnage.



The proper way to pipe a cold storage for storing artificial ice



TRAPEZE HANGER WITH "S. R." FITTINGS

New Trapeze Hangers that Should be Used by all Practical Men. Makes a Clean, Neat Job and is More Efficient than the Old Fashion Hanger.

"S. R." Patented Trapeze Fittings for Practical Hangers

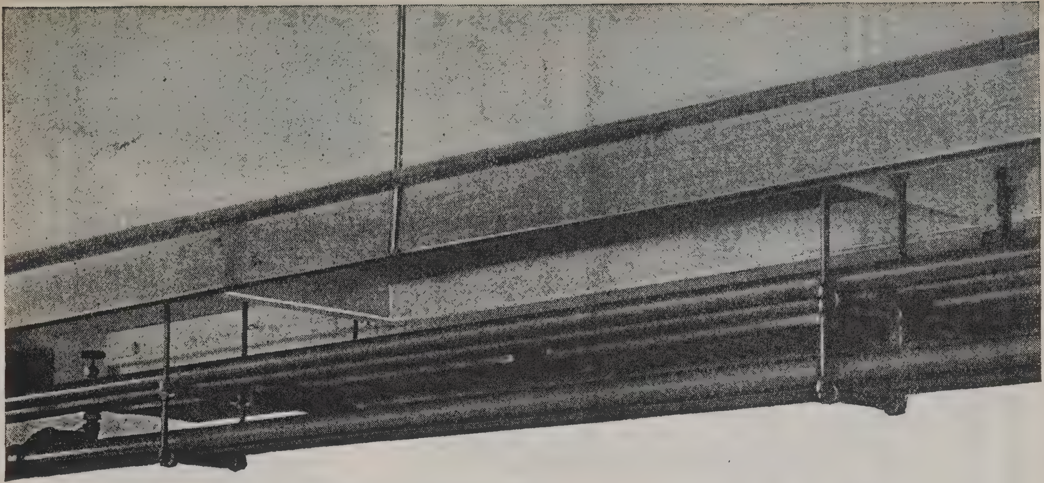
Realizing the necessity for a change from the usual makeshift arrangements such as strap iron and drilled pipe which are generally used for hanging pipe, radiators, etc., from ceilings, beams, or girders, we have designed these TRAPEZE FITTINGS with a view to furnishing a permanent, as well as a neat appearing support.

The illustration shows the TRAPEZE FITTINGS employed in hanging a radiator with its supply and return pipes in addition to plumbers' pipes. Any arrangement or combination can be assembled on the job in a short time by using standard nipples or cut pipe in conjunction with the single and double TRAPEZE FITTINGS and the SLIP END FITTING. This SLIP END FITTING replaces the expensive and non-adjustable forged eye-bolt often used.

All fittings are accurately made from malleable iron and threaded to standard pipe sizes.

Prices are given in pamphlet, which will be sent upon request, by Kehm Brothers, Chicago, Illinois.

A practical man will always use a practical device. This fitting was invented by one of the best heating engineers in this country.



TRAPEZE HANGERS WITH "S. R." FITTINGS

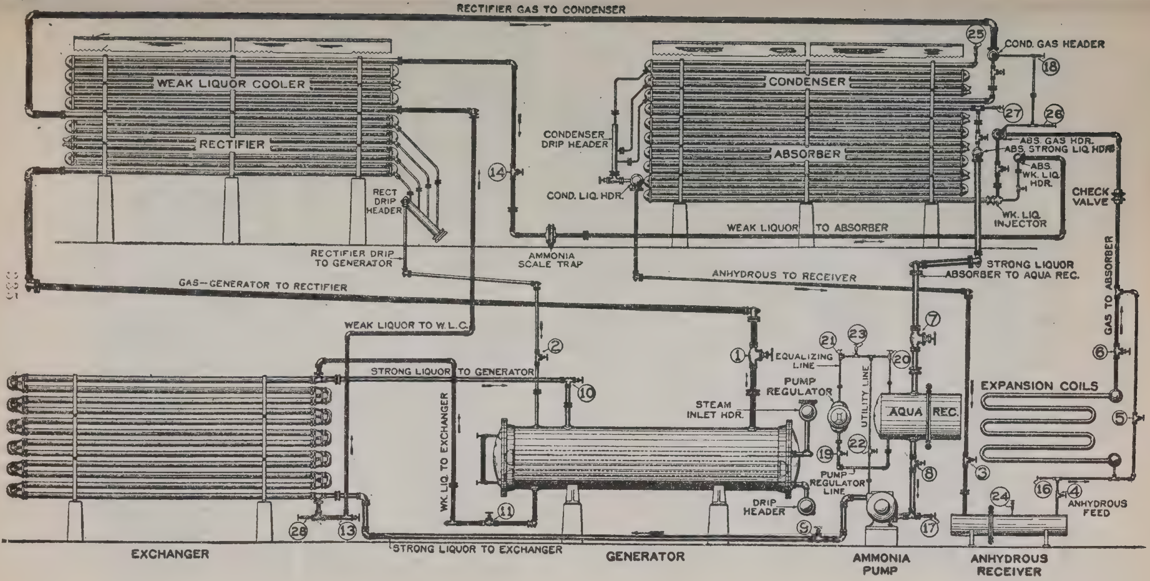
This Illustration Shows the Trapeze Hanger in Position—Steam Pipes Below and Water Pipes Above.

Properties of Saturated Carbonic Acid Gas

Transformed into United States Measures from Professor Schroeter's Table

Temp. Fahrenh.	Press. Atm.	Total Heat B. T. U. Above 32°	Heat of Liquid B. T. U. Above 32°	Latent Heat of Evapor	Weight of Vapor Lbs. per cu. ft.
80	68.0	104.0	63.0	41.0	17.5
70	60.5	103.9	44.0	60.0	13.1
60	52.5	103.6	29.4	74.0	10.6
50	46.2	103.2	17.6	85.6	8.7
40	40.0	102.8	7.5	95.0	7.0
30	34.5	102.2	— 1.8	104.0	5.9
20	29.5	101.6	—10.0	111.0	5.0
10	25.0	100.9	—17.5	118.0	4.17
0	21.2	100.3	—24.0	124.0	3.5
—10	17.7	99.5	—30.9	130.0	2.9
—20	14.8	98.5	—36.5	134.0	2.45
—30	12.4	97.5	—41.5	140.0	2.0

Gallons of Ice Water Cooled per Hour	Floor Space Required in Feet		Capacity Plant Required Tons Ref.	Index Number
	A	B		
50	10	8	1½	AW
125	10	10	4	BW
200	15	14	6	CW
300	20	18	10	DW
400	20	22	14	EW


RECTIFIER GAS TO CONDENSER
WEAK LIQUOR COOLER
RECTIFIER
RECT DRIP HEADER
RECTIFIER DRIP TO GENERATOR
GAS—GENERATOR TO RECTIFIER
14
AMMONIA SCALE TRAP
CONDENSER
ABSORBER
CONDENSER DRIP HEADER
COND. LIQ. HDR.
COND. GAS HEADER
25
18
27
26
ABS. GAS HDR.
ABS. STRONG LIQ. HDR.
ABS. WK. LIQ. HDR.
CHECK VALVE
WK. LIQ. INJECTOR
WEAK LIQUOR TO ABSORBER
STRONG LIQUOR ABSORBER TO AQUA REC.
ANHYDROUS TO RECEIVER
GAS TO ABSORBER
WEAK LIQUOR TO W. L. C.
1
2
7
6
21
23
20
EQUALIZING LINE
UTILITY LINE
STRONG LIQUOR TO GENERATOR
10
PUMP REGULATOR
STEAM INLET HDR.
AQUA REC.
EXPANSION COILS
5
WK. LIQ. TO EXCHANGER
19
22
8
3
PUMP REGULATOR LINE
DRIP HEADER
16
4
24
ANHYDROUS FEED
11
28
13
9
17
STRONG LIQUOR TO EXCHANGER
EXCHANGER
GENERATOR
AMMONIA PUMP
ANHYDROUS RECEIVER

Operation of the Carbondale Absorption Refrigerating Machine.

1. The operation of the Carbondale Absorption Refrigerating Machine is based on the fact that pure water readily absorbs ammonia gas. Pure anhydrous liquid ammonia boils at 28½ degrees below zero Fahrenheit under atmospheric pressure, while water boils at 212 degrees Fahrenheit above zero. A mixture of ammonia and water will have a boiling point somewhere between, depending on the strength of the aqua ammonia solution.

2. The quantity of ammonia that water will absorb depends on the pressure under which the absorption takes place, the temperature of the solution, and the efficiency of the absorber.

3. A strong solution of aqua ammonia is pumped through the Exchanger into the Generator. Steam Heating coils in the Generator heat the solution and drive off the ammonia gas, through the Rectifier, or moisture separator, into the Condenser.

4. From the Condenser the liquid anhydrous ammonia is conducted to the Expansion Coils or Brine Cooler, through the feed valve (4). There it evaporates, gathering the heat from, and thus cooling the objects to be refrigerated.

5. Since strong aqua ammonia is continually pumped into the Generator at the rate of about one-half gallon per minute per ton of refrigeration, and the gas driven off from this aqua into the Condenser, a continuous supply of weak liquor leaves the Generator through the Exchanger and Weak Liquor Cooler to the Absorber, where it absorbs the ammonia gas liberated by the Cooler or Expansion Coils. The resultant strong aqua ammonia is taken from the absorber by the aqua ammonia Pump, forced through the Exchanger into the Generator again, ready to repeat the cycle.

6. This information and diagram is useful to owners and operators, who wish to learn the method by which the Carbondale Exhaust Steam Machine operates. The diagram is of value to experienced engineers, breaking in green operators. It shows a typical Carbondale Atmospheric Type Absorption Refrigerating Machine. We build other types but the principle is the same.

7. Ammonia Gas Connections are shown by Red Lines.

8. Ammonia Weak Liquor Connections are shown by Green Lines.

9. Ammonia Strong Liquor Connections are shown by Red and Green Double Lines .

10. Mark the valves in your plant to correspond to the valves on the diagram. It will help the engineer in case of fire or accident to close the necessary ones promptly, minimizing ammonia loss and preventing other damage.

11. The following instructions, condensed from our instruction Book, are for handy reference.

12. **To Start the Machine:** Assuming that the machine has a normal charge, proceed as follows:

13. Start water circulating through the machine.

14. Start brine pump, making sure that the proper quantity of brine of the proper specific gravity is circulating.

15. Turn steam on generator. Do so gradually.

16. Immediately thereafter start the ammonia pump making sure that valves (8), (9), (10), are open.

17. Open the cooler gas valve (6). Slowly.

18. Open and set weak liquor valve (13).

19. When the generator pressure is raised to that usually carried, open the gas valve (1) and drip valve (2).

20. Open and set the expansion valve (4). The machine is now in regular operation.

21. **To Stop the Machine:** Shut the steam off the generator. During short shut downs leave a little steam on to prevent undue cooling, and leakage through coil tail packing when starting up.

22. Close the expansion valve (4).

23. Stop the ammonia pump, closing suction valve (8).

24. Close the weak liquor valve (13).

25. Close the cooler gas valve (6).

26. Close the rectifier drip valve (2) and gas valve (1).

27. Stop the brine pump.

28. Shut off water supply.

29. For short shut downs, items 25 and 26 may be omitted. All valves should be opened very slowly.

30. **Water Supply:** To secure full capacity it is essential that ample water at proper temperature be provided. Consult the specification or the Carbon-

dale Machine Company to ascertain the correct amount of water.

31. As a general rule the absorber outlet water should not exceed 95 degrees. Sufficient water should be used on the rectifier, to maintain the outlet gas from 20 degrees to 30 degrees Fahrenheit warmer than the ammonia condensing temperature due to the generator pressure.

32. Under proper operating conditions, and water supply, the shortest drip pipe on the rectifier will be very hot, the intermediate pipes successively cooler and the longest pipe fairly cool to the touch.

33. **Steam:** Consult the specifications as to the proper steam pressure to be employed. In general, the steam pressure must be increased if the brine temperature is lowered or the cooling water temperature raised.

34. Ordinarily the steam pressure should not exceed one-third of the generator pressure. Thus with 150 pounds generator pressure, 50 pounds steam pressure is maximum.

35. Keep the air cock on the lower generator header open slightly which frees the coils of air, and indicates if the trap is working properly.

36. **Ammonia Charge:** With the machine in regular operation and a normal charge the proper liquid levels, as indicated by gauge glasses on the various shells, will be as follows:

37. The Generator liquor level will be from one to two inches above the coils.

38. Atmospheric and Double Pipe Absorbers will have at least 12″ of aqua in the receiver, above the pump suction connection. Shell Absorbers will run practically empty.

39. Shell condensers will show 4″ to 6″ of anhydrous in the gauge glass and the receivers of Atmospheric or Double Pipe Condensers will show a similar amount above the outlet to expansion valve.

40. The Brine Cooler should contain enough anhydrous ammonia to frost both gauge cocks, with the cocks closed, and show a flash of soapy liquid in the glass, when the cocks are opened. The gas line should be slightly frosted back to the absorber. This, however, should never frost sufficiently to show frost on the purge line which indicates that liquid ammonia is being carried out of the cooler.

41. **Evaporating or Cooler Pressure:** With a nor-

mal charge, the cooler gauge pressure should correspond to an ammonia temperature from 5 to 10 degrees lower than the temperature of the outgoing brine. The following table shows approximately the pressure corresponding to different outlet brine temperatures.

Temp. Outlet Brine Deg. Fahr.	Cooler Gauge Pressure Pounds Per Square Inch
—20	2½ lbs. vacuum to 0 lbs.
—10	3 lbs. vacuum to 6 lbs.
0	8 lbs. vacuum to 12 lbs.
—10	15 lbs. vacuum to 19 lbs.
—20	23 lbs. vacuum to 27 lbs.

42. If Expansion Coils are used, instead of a Brine Cooler, the normal Evaporating Pressures will be slightly lower than those for a Brine Cooler.

43. **A Brine Cooler Pressure Below** that given in the table for the corresponding temperature indicates:

44. Insufficient ammonia (see par. 40).

45. Cooler needs purging (see par. 64).

46. Brine being circulated with insufficient rapidity (see specification).

47. **If Brine Cooler Pressure Is Too High** it is probably due to one of two causes:

48. Feeding Anhydrous too heavily (see last two lines, par. 40).

49. Air or foul gas in absorber (see par. 71).

50. It is unnecessary to know the strength of the strong and weak aqua to determine if the machine is sufficiently charged. If the conditions outlined in paragraphs 36 to 40 inclusive, are met, the strength of the strong and weak aqua will take care of themselves.

51. **Condensing Pressure.** With clean coils and a good water supply, the generator pressure should not exceed that shown in the table below:

Water Temp. Deg. Fahr.	Generator Gauge Pressure Lbs. Per Sq. In.	Temp. Gas. Leaving Rectifier Deg. Fahr.
50	105	86 to 96
60	125	95 to 105
70	145	102 to 112
80	166	109 to 119
90	192	118 to 128

52. A Generator pressure higher than given in this table, indicates one of three things:

53. Insufficient water supply.

54. Air in the high pressure side of machine.

55. Dirty condenser coils.

56. **Lack of Capacity** is usually attributable to:

57. Insufficient water supply. (See par. 30-31-32.)

58. Insufficient steam pressure. (See par. 33-34-35.)

59. Insufficient flow of brine. (See specification.)

60. Insufficient ammonia charge. (See par. 36 to 40 inc.)

61. Air or non-condensable gas in machine. (See par. 69-70-71.)

62. Dirty Condenser, Absorber or Rectifier coils.

63. Cooler in need of purging. (See par. 64.)

64. **Purging the Cooler.** If some aqua has worked into the Cooler it is usually indicated as follows:

65. A lack of capacity not attributable to other causes, the gauge cocks on the Cooler being frosted as with a normal charge and the Cooler pressure below that shown in table.

66. If on opening the Cooler gauge cocks the liquid looks watery and sluggish, the Cooler pressure is below normal.

67. To remove this aqua, or "Purge" the Cooler, close expansion valve (4) and in about 15 minutes close gas valve (6) and open purge valve (5).

68. After thoroughly draining the Cooler open expansion valve (4) for about half a minute, repeat this several times and when the pressure drops to 5 to 10 pounds below that on the absorber before purging was begun, the Cooler has been completely purged and operation can be resumed.

69. **Removing Air or Foul Gas.** If with clean Condenser coils and ample water supply the condenser pressure remains high, it indicates Air or Foul Gas in the high pressure side of the machine.

70. Air can be removed from the high pressure side, during operation, by opening expansion valve (4) wide for 10 or 15 minutes at intervals of one or two hours. This empties the liquid receiver periodically and allows gas to blow through. The rapid flow of gas thus induced carries the Air or Foul Gas to the low pressure side from which it can be removed through valve (23) see paragraph 71.

As soon as evidence of Air or Foul Gas disappears, this process should be discontinued.

71. To remove Air or Foul Gas from the Absorber blow it from valve (23) into a bucket of water until ammonia gas comes. This is indicated by a crackling sound as the ammonia gas is absorbed, also by the heating of the water. When this occurs, close valve (23).

72. **Leaks.** Stop leaks the moment they appear.

73. **General.** In the season of light load reduce the number of atmospheric or double pipe absorber coils in service to the smallest number required.

74. In cutting out each coil, close the individual controlling valves in the following sequence.

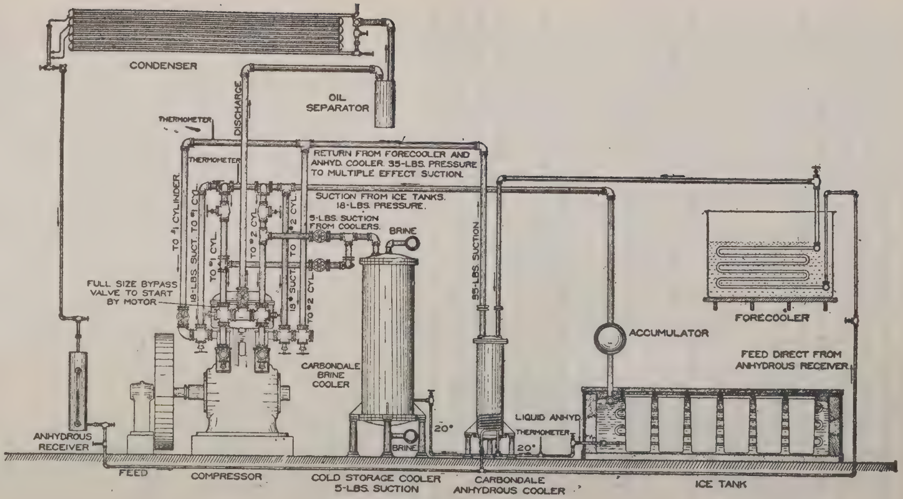
75. Close the weak liquor valve.

76. Close the gas valve.

77. Close the strong liquor valve.

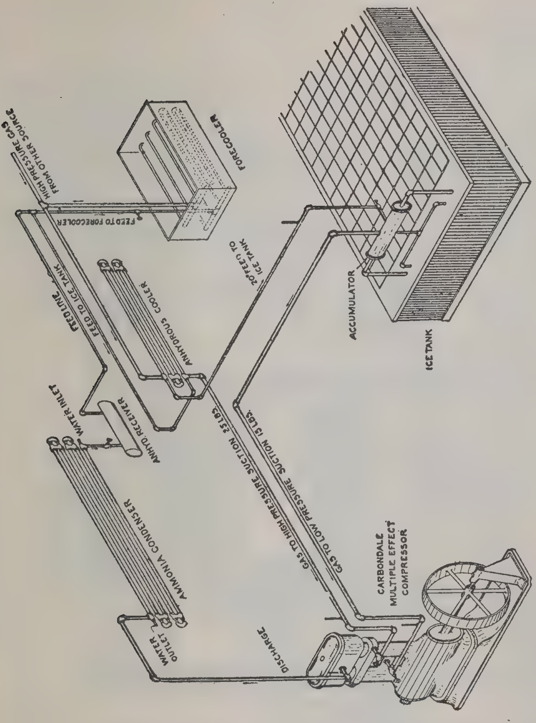
78. In putting the coils back into service the procedure should be reversed.

79. Keep a log of operation, coal, repairs and results. Keep the anhydrous receiver outlet sealed always. Keep the generator coils covered with aqua always and the generator steam pressure as uniform as possible. Keep pipe surfaces clean.


CONDENSER
OIL SEPARATOR
THERMOMETER
DISCHARGE
THERMOMETER
RETURN FROM FORECOOLER AND ANHYD. COOLER. 35-LBS. PRESSURE TO MULTIPLE EFFECT SUCTION.
SUCTION FROM ICE TANKS. 18-LBS. PRESSURE.
5-LBS. SUCTION FROM COOLERS.
BRINE
TO #1 CYLINDER
18-LBS. SUCT. TO #1 CYL.
TO #1 CYL.
TO #2 CYL.
TO #2 CYL.
18# SUCT.
TO #2 CYL.
FULL SIZE BYPASS VALVE TO START BY MOTOR
35-LBS. SUCTION
ACCUMULATOR
FORECOOLER
FEED DIRECT FROM ANHYDROUS RECEIVER.
CARBONDALE BRINE COOLER
LIQUID ANHYD.
THERMOMETER
20°
20°
BRINE
ANHYDROUS RECEIVER
FEED
COMPRESSOR
COLD STORAGE COOLER 5-LBS. SUCTION
CARBONDALE ANHYDROUS COOLER
ICE TANK

CARBONDALE MULTIPLE EFFECT SYSTEM
AS APPLIED TO ICE MAKING & COLD STORAGE

3 TEMPERATURES


FROM OTHER SOURCE HIGH PRESSURE GAS
FORECOOLER
FEED TO FORECOOLER
FEED TO ICE TANK
FEED LINE
ANHYDROUS COOLER
20°FEED TO ICE TANK
ACCUMULATOR
ICE TANK
WATER INLET
ANHYD. RECEIVER
SUCTION 15 LBS.
SUCTION 25 LBS.
GAS TO LOW PRESSURE SUCTION 15 LBS.
GAS TO HIGH PRESSURE SUCTION 25 LBS.
AMMONIA CONDENSER
CARBONDALE MULTIPLE EFFECT COMPRESSOR
WATER OUTLET
DISCHARGE

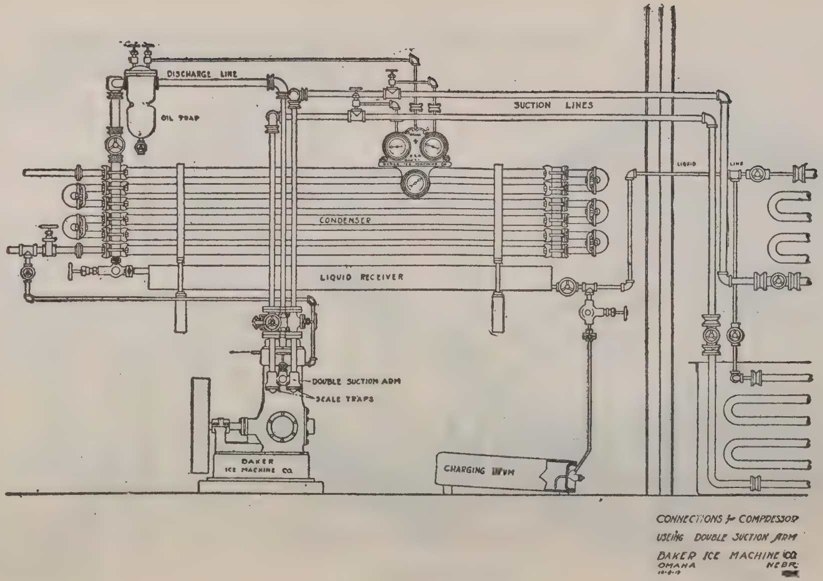
CARBONDALE MULTIPLE EFFECT SYSTEM AS APPLIED TO ICE MAKING

Cubic feet displaced by different size ice cans.

Ice Cake	Size Ice Cans Size	Displace brine in ice Tank
100 lbs.	8 x16 x32	1.6 cu. ft.
200 "	11½x22½x32	3.2 " "
300 "	11½x22½x44	5.0 " "
400 "	11½x22½x57	6.5 " "

For Direct Expansion Coils in ice tank-top feed allow 300 lineal feet of 1¼-inch pipe.

For flooded coils properly designed and not over 350 feet of 1¼-inch pipe per coil allow 220 lineal feet per ton of ice capacity.


DISCHARGE LINE
OIL TRAP
SUCTION LINES
LIQUID
LINE
CONDENSER
LIQUID RECEIVER
DOUBLE SUCTION ARM
SCALE TRAPS
BAKER ICE MACHINE CO.
CHARGING DRUM
CONNECTIONS for COMPRESSOR
USEING DOUBLE SUCTION ARM
BAKER ICE MACHINE CO.
OMAHA NEBR.

Balser Ice Machine. Latest model.

Arrangement of an Ice Plant.

1. Boiler.
2. Feed Pump.
3. Steam Engine.
4. Compressor.
5. Oil Trap for Ammonia.
6. Condenser.
7. Liquid Ammonia Receiver.
8. Oil Separator.
9. Purifier.
10. Steam Condenser.
11. Hot Skimmer.
12. Reboiler.
13. Cooling Coil.
14. Filters.
15. Cold Water Reservoir.
16. Filling Hose.
17. Can Filler.
18. Freezing Tank.
19. Hoist.
20. Thawing Apparatus.

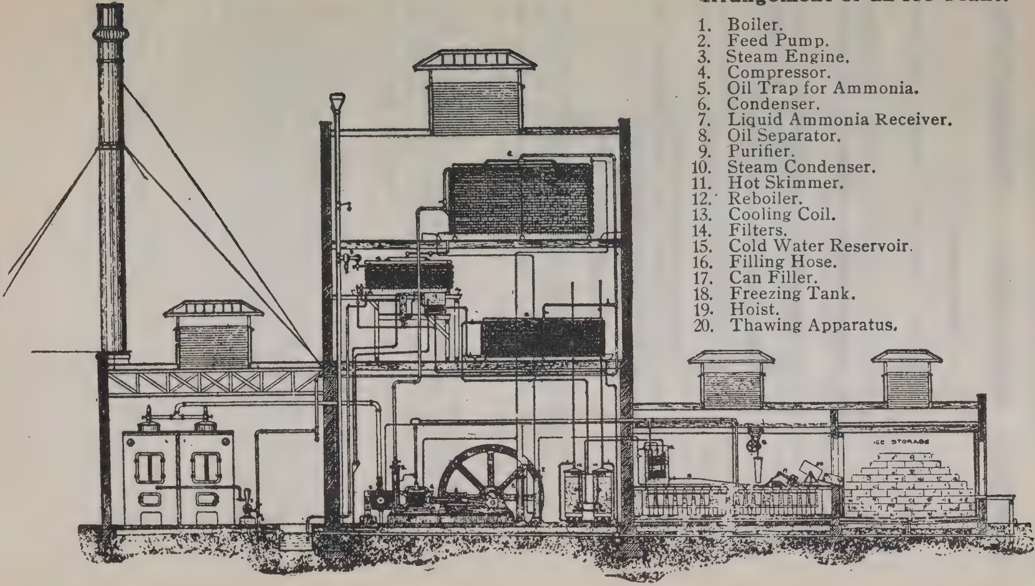


Fig. 16

GENERAL AND USEFUL INFORMATION.

Ammonia.

Ammonia is composed of one part nitrogen and three parts hydrogen.

Pure ammonia liquid is colorless, having a peculiar alkaline odor and caustic taste. It turns red litmus paper blue or white litmus paper red.

The boiling point of ammonia depends on its purity, and is about 28½° below zero at atmospheric pressure. The purer the liquid the lower its boiling point.

One pound of liquid ammonia at 32° F. will occupy 21.017 cubic feet of space when evaporated at atmospheric pressure.

The specific heat of ammonia gas as determined by Regnault is 0.50836.

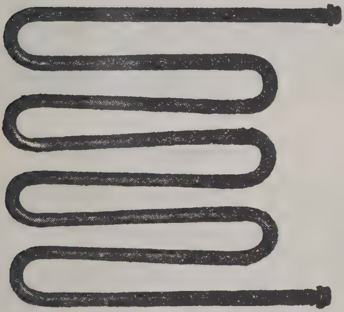
Heat.

One British Thermal Unit (B. T. U.) is the quantity of heat required to raise one pound of water at 32° F. to 33° F., or the amount of heat that must be extracted from one pound of water at 33° F. to reduce it to 32° F.

The latent heat of ice is 142 B. T. U. That is to say, one pound of ice at 32° F. will require 142 B. T. U. to melt it into water at 32° F., or 142 B. T. U. must be extracted from water at 32° F. to freeze it into ice at 32° F.

One ton of refrigeration is the amount of heat absorbed by the melting of 2,000 pounds of ice at 32° F. into 2,000 pounds of water at 32° F., or the amount of heat that must be extracted from 2,000 pounds of water at 32° F. to reduce it to 2,000 pounds of ice at 32° F., or $2{,}000 \times 142 = 284{,}000$ B. T. U.

Bent Pipe Efficiency



Bent Pipe is far superior to that of screw pipe. The efficiency of bent pipe for coil work for either refrigeration or heating is far superior to that of screw pipe on account of expansion, contraction and friction. In this way more back pressure can be carried.

In order to use bent pipe coils more room must be provided for, as bent coils take up more space. The shortest bend that inch and a quarter pipe will stand is 4 inches, center to center. This is the size that is ordinarily used on small work, such as creameries, butcher shops and hotels. Two inch pipe would take up a great deal of room. That is for refrigeration work like cold storage and ice storage for ice-making plants. But it pays and saves money in the long run to use bent pipe coils, doing away with leaks entirely.

Carbonic Anhydride Systems

Carbonic anhydride compressors have a displacement of about 900 to 1200 cubic inches or more per minute per ton of refrigerating capacity, depending upon suction pressure of liquid carbonic gas, when changing from a liquid state into a gaseous state in the evaporating coils. The carbonic system is highly recommended for use in department stores, hotels, office buildings, hospitals, factories, on ships, in chemical or manufacturing processes, where an efficient, odorless and harmless refrigerant is desirable.

Condensing Water

One and one-half gallons to two gallons of water per minute should be minimum allowance of deep well or city water supply per ton of refrigerating capacity of a refrigerating plant with a standard double pipe condenser, water entering condenser at a temperature of 70 degrees Fahr. and leaving at a temperature of about 90 degrees Fahr. Higher temperature water requires a greater quantity per ton of refrigeration. An allowance of four gallons of water per minute.

Direct Expansion Systems

The refrigerant is expanded through coils placed directly in refrigerator or room to be cooled and in case of a large number of coils or rooms difficulty is experienced in regulating many expansion valves. Refrigeration is not delivered when plant is shut down. While theoretically very efficient, this system requires more attention from operator than the brine system and in case of a leak the refrigerant leaks into the cooling room or building, which is very undesirable. The conditions are very few where direct expansion is preferred to the brine circulating system for cooling food products, except where very low temperatures are required below freezing point of water.

Cooled Air and Ventilation

The seating capacity of a restaurant or dining room, including aisle space when crowded should allow fifteen square feet of total floor space per person, while a theatre should allow 7 square feet. The electric lighting allowance is usually one watt per square foot of floor space for a dining room or restaurant. One person generates 400 B. T. U. per hour. One 50 watt lamp generates 170 B. T. U. per hour. In cooling circulating air in hot weather for ventilation of restaurants, offices, in temperate climates, allow three tons capacity.

Brine Circulating Systems

A tank of calcium chloride brine is cooled by a refrigerant expanding through coils or cooler surface in intimate contact with brine. The brine is pumped at the rate of five gallons per minute per ton of refrigeration through various coils in the refrigerators or room to be cooled at a pressure varying from 20 to 100 pounds per square inch. Brine feed and return mains are installed under the multiple system the brine circulating through a coil returning to tank after rising about five degrees in temperature. Brine mains are of such size that the friction loss of pressure due to circulation of brine is not greater than 3½ pounds per 100 feet of feed or return main. The brine system is recommended where there are a great number of refrigerators scattered throughout a plant. Brine valves consist of an ordinary gate or globe valve and are easier to regulate than an expansion valve. Refrigeration can be furnished for a few hours in case compressor is shut down. The brine acts similar to a storage battery in an electric lighting plant. The practical advantages of the brine system more than balance the slight loss of refrigeration through radiation and changing mediums.

Cold Storage Room Capacity

One 60 pound butter tub occupies 2¾ cubic feet of space.

One 30 dozen case of eggs occupies 3 cubic feet of space.

One 60 pound cheese box occupies 2 cubic feet of space.

One 3 bushel barrel apples occupies 10 cubic feet of space.

One ton of ice occupies about fifty cubic feet.

Add 25% to above to allow for passageway in laying out floor space of cold storage rooms. When piled six feet high in cold storage-rooms one ton of cheese occupies 7 square feet, one ton of butter about 8 square feet, 100 cases of eggs about 30 square feet of floor space. Cold storage goods packed in boxes are usually piled so as to not cause a greater load on floor than about 250 pounds per square foot.

Refrigerating and Heat Units

The delivery of one ton of refrigerating capacity by a refrigerating plant is equivalent to a rate of 2000 pounds of ice melting in 24 hours, a rate of 284,000 British thermal units (B. T. U.) in 24 hours or a rate of 200 B. T. U. per minute. In English speaking countries, the mean heat unit is 1/180 of the heat required to raise one pound of water from freezing point to boiling point and this quantity is termed a British Thermal Unit (B. T. U.). The unit of heat used by French and Germans is called the Calorie and is equal to one kilogram (2.205 pounds) of water raised one degree centigrade (1.8 degree Fahr.) and is equal to 3.967 B. T. U.

Ammonia Compression Systems

Ammonia compressors have a displacement of about 7000 to 8500 cubic inches or more per minute per ton of refrigerating capacity, depending upon the suction pressure of liquid ammonia when changing from liquid state into a gaseous state in the evaporating coils, or evaporating tank. The ammonia system has found its greatest favor among builders of breweries, packing houses, commercial ice making plants and large commercial cold storage enterprises.

Ice Cream

To cool the mix, freeze and harden ice cream at the rate of 50 gallons per hour, requires a standard rated refrigerating plant of about 10 tons capacity. Freezing the ice cream is best accomplished with brine varying in temperature from zero to 10 degrees Fahr. and the dry hardening of ice cream requires a zero insulated room with a vestibule and to obtain these low temperatures requires a low suction pressure, so that a standard 10 ton compressor will deliver about 8 tons refrigeration under actual operating conditions. Subdividing the refrigerating requirements the following is obtained:

Mixer and freezer requires 1000 B. T. U.'s per gallon.

Dry hardening room (12 hours) requires 1000 B. T. U.'s per gallon.

Sweet cream storage room requires 200 B. T. U.'s per gallon.

The commercial 40 quart brine ice cream freezer holds about 10 gallons of cream and circulating 14 gallons of brine per minute, not exceeding 10 degrees Fahr. in temperature will freeze the batch in 10 minutes.

About 4½ tons portion of the total capacity is required to cool the brine for 50 gallons of cream per hour in the freezer and mixer.

Cream hardens in about 12 hours in a zero dry hardening room, will usually contain one lineal foot of 1¼ inches direct expansion coil for one cubic foot of space of room insulated with 6 inches to 8 inches of pure cork board. About 1000 cubic feet hardening room is required for a 500 gallon per day plant, freezing cream in 10 hours, which would require 4 tons portion of the total capacity of the plant. Sweet cream storage room for a 500 gallon per day plant would require about 1 ton portion of the total refrigerating capacity.

Fur Storage Rooms—(25 Degrees Fahr.)

Fur storage rooms usually require one ton capacity per 3000 cubic feet of space to maintain room at about 25 degrees Fahr. when insulated with 5 inch pure cork board and enclosed air is recirculated about five times per hour through cooling coil bunker. Small rooms less than 7000 cubic feet capacity require about one ton capacity per 2000 cubic feet of space.

Cooling Rooms—(60 Degrees Fahr.)

To cool wrapping rooms, or chocolate cooling rooms insulated with 2 inch cork board allow one ton total capacity per 3000 to 4000 cubic feet space. Allow also extra one ton capacity per every two dozen employees radiating body heat continually in room. Air should be recirculated ten times per hour through coil bunker. All doors should be insulated and double glass windows installed. Five cubic feet fresh air per minute per employee, in addition to the air leaking into cooler from opening and shutting of doors, etc., will furnish ample supply of air for breathing. In very small chocolate rooms 7000 cubic feet or below allow 2000 cubic feet per ton.

PROPERTIES OF REFRIGERANTS

Carbonic Gas

Temp. Fahr. (No superheat)	80°	70°	60°	20°	10°	0°	—10°
Pressures Atmospheres ...	68	65.5	52.5	29.5	25	21.2	17.7
Weight vapor in lbs. per cubic foot	17.5	13.1	10.6	5.0	4.17	3.5	2.9

Ammonia

Temp. Fahr. (No superheat)..	80°	70°	60°	20°	10°	0°	—10°
Pressure gage lbs. per sq. in...	140	115	93	33	23.6	15.67	9
Weight vapor in lbs. per cu. ft..	0.52	0.44	0.37	0.17	0.14	0.10	0.09

Sulphur Dioxide

Temp. Fahr. (No superheat)	77°	59°	23°	5°	—4°
Pressure gage lbs. per sq in	42	25	3.3	—3	—6
Weight vapor lbs. per cu. ft	67	.48	.23	.15	.12

Properties of Calcium Chloride Brine

Freezing point below zero	— 19.1
Specific heat	.718
Lbs. calcium chloride per gallon of solution	3.224
Lbs. calcium chloride per cubic foot of solution	24.1
Weight of gallon of solution	10.13
Weight of one cubic foot of solution	95.8
Specific gravity at 60° Fahr	1.215
Suction pressure ammonia gage (lbs. sq. in.)	4.00
Suction pressure carbonic gage (atmospheres)	14.8
Degree salometer	102.

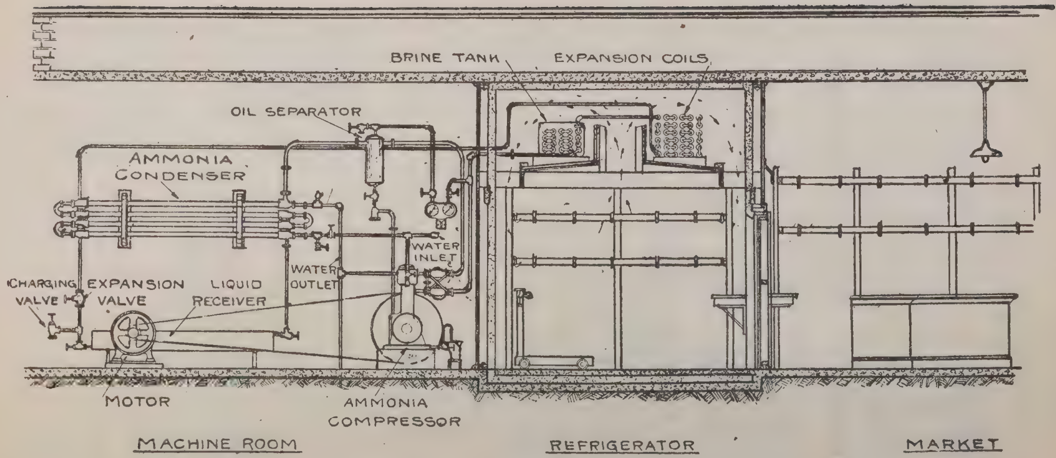
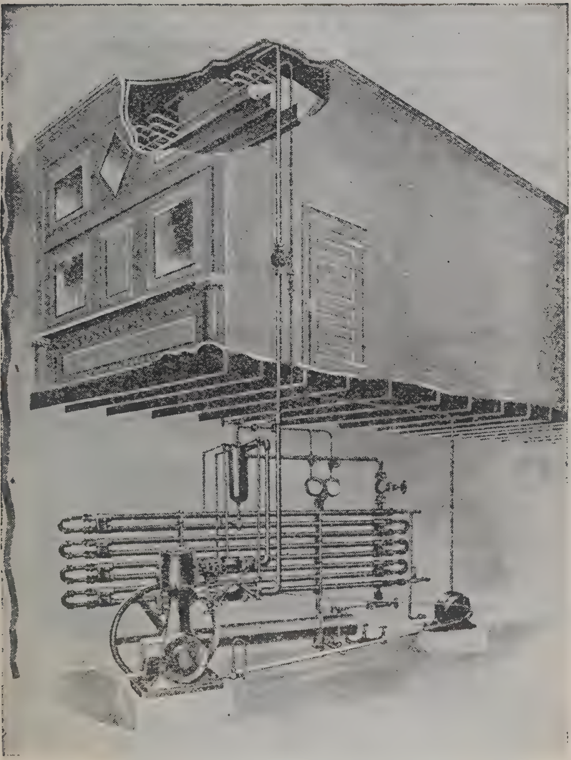
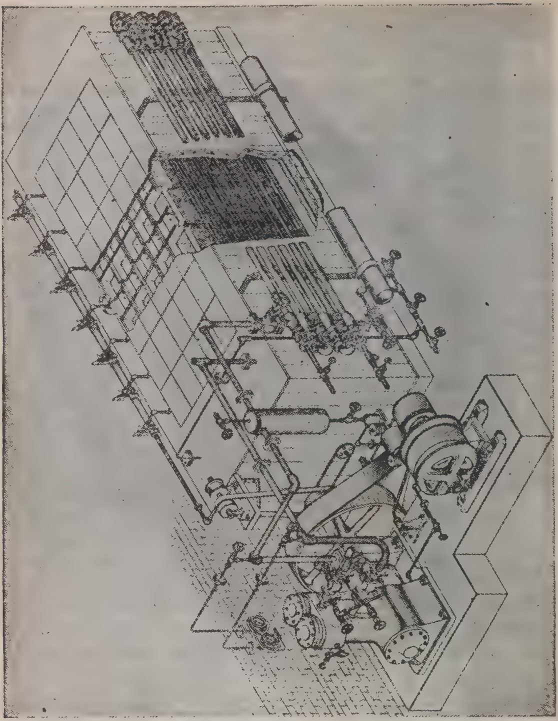

BRINE TANK
EXPANSION COILS
OIL SEPARATOR
AMMONIA CONDENSER
WATER INLET
WATER OUTLET
CHARGING VALVE
EXPANSION VALVE
LIQUID RECEIVER
MOTOR
AMMONIA COMPRESSOR
MACHINE ROOM
REFRIGERATOR
MARKET

Diagram showing the names of various parts of a typical small Vilter Installation.



Typical layout for a butcher plant using the Vilter Machine

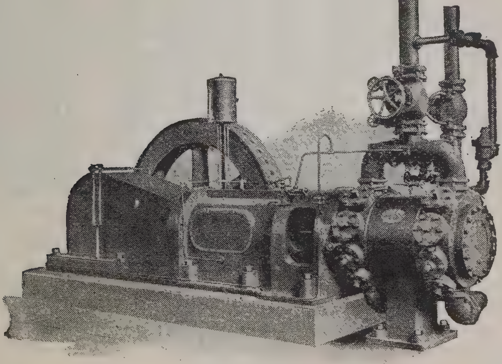


Layout for a small icemaking plant using the Vilter Compressor

High Speed Ammonia Compressor.

The illustration appearing on this page is of a Vilter high speed ammonia compressor which is built by the Vilter Manufacturing Company of Milwaukee, Wisconsin. The high speed ammonia compressor has been developed in the past few years and marks a distinct advance in ammonia compressor construction. There are several advantages that this type of machine has over the former slow speed type of machine which are principally that smaller floor space is required for the same amount of refrigeration, and also that it is now possible to have direct connection to electric motors and high speed steam, oil or gas engines, instead of belting the ammonia compressor to the motor or engine, thereby eliminating the power loss which is always present when belt or rope drive is used.

It must be remembered that there is very little reduction in the weight of the compressor as compared with the weight of a slow speed compressor of same capacity, neither does the piston speed become very high as the stroke is shortened and the speed is thus kept down. It was necessary to utilize as entirely different type of valve than the Poppet valve which has been used heretofore in the slow speed compressor. In the Vilter high speed compressor the Vilter plate valve is used, which is a very light valve as compared to a Poppet valve, but at the same time very efficient. The lubricating requirements are more severe in a high speed compressor than in the Vilter high speed compressor. This problem has been satisfactorily solved by the use of an automatic oiling system which supplies the right amount of oil at the various parts of the machine where it is required.



PROPERTIES OF AMMONIA.

From Marks' Mechanical Engineers' Handbook.

Temperature, deg. Fahr.	Pressure, lb. per square inch, abs.	SPECIFIC VOLUME		HEAT CONTENT		Heat of vaporization	Internal energy of vaporization	ENTROPY	
		Of liquid, cubic feet per pound	Of sat. vapor, cubic feet per pound	Of liquid	Of sat. vapor			Of liquid	Of vaporization
—40	10.12	0.0234	25.45	—75.3	526.6	601.9	554.2	—0.1653	1.4343
—35	11.74	0.0235	22.14	—70.2	528.2	598.3	550.2	—0.1531	1.4090
—30	13.56	0.0236	19.35	—65.0	920.8	594.7	546.2	—0.1410	1.3842
—25	15.61	0.0238	16.95	—59.8	531.3	591.1	542.1	—0.1290	1.3598
—20	17.91	0.0239	14.89	—54.6	532.8	587.4	538.0	—0.1171	1.3360
—15	20.46	0.0240	13.15	—49.4	534.3	583.6	533.9	—0.1054	1.3126
—10	23.30	0.0241	11.63	—44.2	535.7	579.9	529.8	—0.0938	1.2896
— 5	26.46	0.0242	10.32	—38.9	537.1	576.1	525.6	—0.0824	1.2671
0	29.95	0.0244	9.19	—33.7	538.5	572.2	521.4	—0.0709	1.2449
5	33.79	0.0245	8.20	—28.4	539.9	568.3	517.1	—0.0595	1.2231
10	38.02	0.0246	7.34	—23.2	541.2	564.4	512.9	—0.0483	1.2017
15	42.67	0.0248	6.583	—17.9	542.5	560.4	508.6	—0.0372	1.1806
20	47.75	0.0249	5.920	—12.6	543.7	556.3	504.2	—0.0262	1.1599
25	53.30	0.0250	5.336	— 7.3	545.0	552.2	499.8	—0.0153	1.1395
30	59.39	0.0252	4.820	— 1.9	546.2	548.1	495.4	—0.0044	1.1194
35	65.91	0.0253	4.364	+ 3.5	547.4	543.9	491.0	+0.0005	1.0996
40	73.03	0.0255	3.959	8.9	548.5	539.7	486.5	0.0173	1.0801
45	80.75	0.0256	3.599	14.3	549.7	535.3	481.9	0.0280	1.0609
50	89.09	0.0258	3.278	19.8	550.8	531.0	477.3	0.0387	1.0419
55	98.03	0.0259	2.992	25.3	551.9	526.5	472.7	0.0494	1.0231
60	107.7	0.0261	2.734	30.9	552.9	522.0	468.0	0.0601	1.0046
65	118.1	0.0263	2.503	36.5	554.0	517.5	463.3	0.0708	0.9863
70	129.2	0.0264	2.296	42.1	555.0	512.8	458.5	0.0813	0.9683
75	141.1	0.0266	2.109	47.8	556.0	508.1	453.7	0.0019	0.9504
80	153.9	0.0268	1.940	53.6	557.0	503.4	448.8	0.1025	0.9328
85	167.4	0.0270	1.788	59.4	557.9	498.5	443.9	0.1132	0.9153
90	181.8	0.0271	1.650	65.3	558.9	493.5	438.9	0.1238	0.8980
95	197.3	0.0273	1.524	71.3	559.8	488.5	433.9	0.1344	0.8808
100	213.8	0.0275	1.408	77.3	560.7	483.4	428.7	0.1450	0.8638
105	231.2	0.0277	1.305	83.4	561.6	478.2	423.5	0.1557	0.8469
110	249.6	0.0280	1.210	89.6	562.5	472.9	418.3	0.1664	0.8302
115	269.2	0.0282	1.122	95.9	563.3	467.4	412.9	0.1772	0.8135
120	289.9	0.0284	1.042	102.2	564.2	461.9	407.5	0.1881	0.7969
125	311.6	0.0286	0.970	108.7	565.0	456.3	402.0	0.1990	0.7805

AMMONIA CHARGE.

As already stated, aqua ammonia is contained in the generator, exchanger and absorber, and anhydrous ammonia is contained in the condenser and cooler. With the machine in regular operation, and a normal charge, the following will be the condition as indicated by the gauge glasses on the various shells:

The generator will have from 1 in. to 2 in. of liquor covering the coils.

The absorber will contain ammonia as follows, depending on the type, viz.:

Tubular absorbers will have about 1 in. of aqua ammonia over the top of the top row of tubes.

Atmospheric and Double Pipe absorbers will have at least 12 in. of aqua ammonia in the aqua receiver above the pump suction connection.

Shell absorbers will run practically empty and the gauge glass will show aqua ammonia as nearly as possible level with the lower flange joint of the shell and head.

The shell condenser will show 4 in. to 6 in. of anhydrous ammonia in the gauge glass while the receivers of atmospheric or double pipe condensers will show a similar amount in the gauge glass above the outlet to the expansion valve, or at least sufficient to cover the outlet so that gas cannot blow through.

It is advisable when the proper levels in the different vessels are determined to tie a string around the gauge glass. This will indicate any change from the normal levels.

The brine cooler will have enough anhydrous ammonia in it to frost over both gauge cocks, and show a flash of soapy fluid in the glass when the gauge cocks are opened. The gas line should be slightly frosted back to the absorber; this, however, should never frost sufficiently to show frost on the purge line, as this would indicate that liquid ammonia was being carried out of the cooler.

It is not necessary to know the strength of the strong and weak aqua to determine whether or not the machine is sufficiently charged. If the above conditions are met, the strength of the strong and weak aqua will take care of themselves.

BRINE CHARGE.

We recommend the use of 73 to 75 per cent calcium chloride, free of salt and magnesia, for making the brine for the Carbondale refrigerating machine. This should usually be carried at a specific gravity ranging from 1.225 to 1.250 for cold storage plants, and near 1.175 for ice tanks. The following table will show the temperature at which various calcium brine solutions freeze:

TABLE I.

Properties of 73 to 75 Per Cent Calcium Chloride Solution.

Specific Gravity	Per Cu. Ft. Solution	Per Gal. Solution	Freezing Point
1.283	32.70 lbs.	4.37 lbs.	—54.40° F.
1.272	31.30	4.18	—46.20
1.261	30.00	4.01	—39.28
1.250	28.06	3.76	—32.6
1.225	25.06	3.36	—19.5
1.200	22.05	2.95	— 8.7
1.175	19.15	2.56	Zero
1.150	16.26	2.18	+ 7.5
1.125	13.47	1.80	+13.3
1.100	10.70	1.43	+18.5

Ordinary salt brine is absolutely unsuitable for use with a brine cooler as it is apt to freeze and burst the coils or tubes. It can, however, often be used in an ice tank with a certain amount of success.

The following table gives the properties:

TABLE 2.

Properties of Salt Brine.

Degrees Beaume 60° Fahr.	Degrees on Salometer 60° Fahr.	Specific Gravity 60° Fahr.	Per cent. of Salt by Weight	Weight of One Gallon	Weight of One Cubic Foot	Freezing Point Degrees Fahr.	Specific Heat
0	0	1.	0	8.35	62.4	32.	1.
1	4	1.007	1	8.40	62.8	31.8	0.992
5	20	1.037	5	8.65	64.7	25.4	0.960
10	40	1.073	10	8.95	66.95	18.6	0.892
15	60	1.115	15	9.30	69.57	12.2	0.855
19	80	1.150	20	9.60	71.76	6.86	0.829
23	100	1.191	25	9.94	74.26	1.00	0.783

SPRINKLER SYSTEMS AND FILTRATION PLANTS

RULES FOR SPRINKLING SYSTEM

WATER SUPPLIES.

Double Supply.—Two independent supplies are absolutely necessary for a standard equipment. At least one of the supplies to be automatic and one to be capable of furnishing water under heavy pressure. The choice of water supplies for each equipment to be determined by the Underwriters having jurisdiction.

Size of Connection.—Connection from water supply or main pipe system to sprinkler riser to be equal to or larger in size than the riser.

PUBLIC WATER WORKS SYSTEM.

(Rules also applicable to private reservoir and stand pipe systems.)

1. **Pressure Required.**—Should give not less than 25 pounds static pressure at all hours of the day at highest line of sprinklers.

Where the normal static pressure complies with the above, the supply to be also satisfactory to the Underwriters having jurisdiction, in its ability to maintain 10 pounds pressure at highest sprinklers, with the water flowing through the number of sprinklers judged liable to be opened by fire at any one time.

Size of Mains.—Street mains should be of ample size, in no case smaller than 6 inches.

Dead Ends.—If possible, avoid a dead end in street main by arranging main to be fed at both ends.

Meter.—No water supply for sprinklers to pass through a meter or pressure regulating valve, except by special consent.

STEAM PUMP.

Type.—To be in accordance with the National Standard specifications.

Capacity.—To be determined by Underwriters having jurisdiction in each instance, but never less than 500 gallons rated capacity per minute.

8. **Pump for Filling.**—It is desirable to have water fed to tank by a pump so that proper water level may be restored at any time without reducing air pressure.

3. Risers and Feed Mains.—Central feed risers:
1½ inch. Not over 6 heads.
2 inch. Not over 10 heads.
2½ inch. Not over 20 heads.
3 inch. Not over 36 heads.
3½ inch. Not over 55 heads.
4 inch. Not over 72 heads.

For gridiron side feed risers, use the same sizes counting to the center of each line. If number on line is odd the center head may be neglected in figuring size of side risers except that pipe feeding both risers must take into account all sprinklers which it feeds. Where feed main (including risers to the first branch line) is over twenty-five feet in length feed main to be at least a size larger than the tables require. Where there is more than one riser size of feed mains to be determined by the Underwriters having jurisdiction but never to be less than the full equivalent of the two largest risers.

11. Drip Pipes.—Drip pipes to be provided to drain all parts of the system. Drip pipes at main risers to be not smaller than two (2) inches, and when exposed to the weather to be fitted with hood or down-turned elbow to prevent stoppage with ice.

12. Drainage.—All sprinkler pipe and fittings to be so installed that they can be thoroughly drained, and, where practicable, all piping to be arranged to drain at the main drips. On wet pipe systems the horizontal branch pipes to be pitched not less than ¼ inch in 10 feet. (See also Sec. H 2.)

12. Exhaust Pipe.—Each pump to be provided with an independent exhaust pipe, free from liability to back pressure and equipped with an open drain pipe at lowest point.

13. Steam Pressures.—Steam pressure of not less than 50 pounds to be maintained at the pump at all times.

14. Boilers.—Provision to be made for sufficient steam power to run pump to full rated capacity; not less than 40 H. P. for each 250 gallons rated capacity of pump. Boilers to be supplied with ample water supply not liable to be crippled in case of fire. Where forced draught is necessary, provisions should be made for safe, independent control of the same.

2. **Pipe Size.**—To be not less than four (4) inches in size and fitted with a straightway check valve, but not with a gate valve. Siamese connections to be provided with check valves in the "Y."

A ¾-inch drip pipe and valve to be installed so as to properly drain the piping between the check valve and the outside hose coupling.

Connections to be so located as to provide for prompt and easy attachment of hose.

3. **Where Attached.**—To equipments having a single riser, attach on the system side of the gate valve in the riser if a wet system, but on the supply side if the dry valve if a dry system.

To equipments having two or more risers, attach on the supply side of the gate valves, so that with any one riser shut off the supply will feed all the remaining sprinklers.

4. **Threads.**—Each hose connection to be made of good brass, having thread to fit coupling of public fire department. Malleable iron or brass caps, secured to connection by chains and having suitable lugs at sides to fit spanner wrench of public fire department, to be provided for each connection.

Each hose connection to be designated by raised letters at least 1 inch in size, cast in the fitting in a clear and prominent manner, and reading: "Auto. spkr."

2. **Painting and Bronzing.**—Where pipes are painted or bronzed for appearance, the moving parts of sprinkler heads should not be so coated.

3. **Piling of Stock.**—Sprinkler heads to be free to form an unbroken spray blanket for at least 2 feet under the ceiling from sprinkler to sprinkler and sides of room. Any stock piles, racks or other obstructions interfering with such action are not permissible.

4. **Settling of Building.**—Where a building settles and deprives a dry pipe system of its drainage, the ends of lines should not be raised to violate Sec. B, 3. The drainage should be restored by shortening the vertical piping.

5. **Position of Deflector.**—Notice that it is the deflector of a sprinkler which should be at least 3 inches (and not over 10 inches) from ceiling or bottom of joists; 6 to 8 inches is the best distance with average pressure and present types of sprinklers. (See Sec. B, 3.)

(d) Heating: Where there is exposure to cold, tank to be provided with a steam coil inside and at the bottom. Coil to be made of brass or galvanized iron to prevent rusting and provided with a return pipe to the boiler room, or, tank to be provided with a direct steam pipe from boilers discharging into water near top and fitted with a check valve and perforated fitting to prevent siphoning.

2. Hydrant Mains.—No. 4-inch pipe to be used.

3. For Pipes Extending to a Dead End:—

a. Allow 200 feet 6-inch pipe with one 3-way hydrant.

b. Allow 500 feet 6-inch pipe with one 2-way hydrant.

This might be extended in special cases.

c. Allow 1,000 feet 8-inch pipe with one 3-way hydrant.

d. Allow 500 feet 8-inch pipe with one 4-way hydrant or its equivalent in hose streams.

e. Allow 300 feet 8-inch pipe to first hydrant, where there is a hydrant equivalent of 6 streams.

SECTION S—MISCELLANEOUS RULES.

1. Circulation in Pipes.—Circulation of water in sprinkler pipes is very objectionable, owing to greatly increased corrosion, deposit of sediment and condensation drip from pipes; sprinkler pipes not to be used in any way for domestic service.

Location.—To be so located on the premises as to be free from damage by fire or other cause. Pump room should be readily accessible and provide easy and safe egress for attendant.

PRESSURE TANK.

Capacity.—Total capacity of tank to be specified by Underwriters having jurisdiction, but not less than 4,500 gallons, except by special permission.

Location.—Tank not to be located below upper story of building.

Tank Service.—Tanks to be used as a supply to automatic sprinklers and hand hose only.

Capacity.—Total capacity of tank to be specified by Underwriters having jurisdiction, but not less than 4,500 gallons, except by special permission.

Location.—Tank not to be located below upper story of building.

GRAVITY TANK.

1. **Capacity.**—To be specified by the Underwriters having jurisdiction. In no case to be of less than 30,000 gallons capacity.

Capacity of the tank to be computed from the net depth measured from the top of the discharge pipe to bottom of overflow pipe.

2. **Elevation.**—Elevation of bottom of tank above highest line of sprinklers on system which it supplies to be specified by the Underwriters having jurisdiction. The greater the elevation of a gravity tank the less likelihood of inefficient service. Underwriters having jurisdiction are urged to have such tanks placed at the greatest practicable elevation.

3. **Tank Service.**—Tank to be used as a supply to automatic sprinkler system only, except that, at the discretion of the Underwriters, tank may be made larger than called for, and so arranged that the excess supply only may be used for other purposes.

4. **Independent Drain.**—Provision to be made to drain each tank independently of other tanks and the sprinkler system. The practice of placing drain valves at lower levels and accessible from the exterior of buildings is not approved.

5. **Test.**—Tank to be tested and proved tight at a hydrostatic pressure of at least 25 per cent. in excess of the normal working pressure required. Water then to be drawn off to the two-thirds line and tank tested at the working air pressure required. In this condition and with all valves closed, tank not to show loss of pressure in excess of ½ pound in 24 hours.

6. **Fittings and Connections.**—(a). Gage Glass: To be placed on the end of horizontal and side of upright tank so that the two-thirds line will be at the center of the glass. Gage glass valves to be of the best quality angle globe pattern.

The two valves in the water gage connections to be kept closed and opened only to ascertain the amount of water in the tanks; as breaking of or leakage about glass will cause the escape of pressure.

SECTION P—STEAMER CONNECTIONS.

1. **Recommendations.**—In addition to the above required double supply, it is recommended that a hose inlet pipe to sprinkler system be provided for connection from hose or steamer of public fire department.

6. Hanging Stock to Piping.—Sprinkler piping should not be used for the support of stock, clothing, etc.

7. Alterations.—It is not permitted to change, plug up or remove the fittings pertaining to dry pipe valve, pressure tanks, pumps, gages, etc. If such fittings leak or become deranged, they are to be put in order.

8. Extra Sprinklers.—There should be maintained on the premises a supply of extra sprinklers (never less than six), to promptly replace any fused by fire or in any way injured.

9. Use of High Degree or Hard Sprinklers.—High degree sprinklers should be used only when absolutely necessary. When used, the fusing points should be as low as the conditions will safely permit. Underwriters having jurisdiction should be consulted in each instance before the installation of high degree sprinklers.

Ordinary degree sprinklers should be substituted for high degree sprinklers where the latter are made unnecessary by change in occupancy.

10. Hand Hose Connections.—Hand hose to be used for fire purposes only, may be attached to sprinkler pipes within a room under the following restrictions:

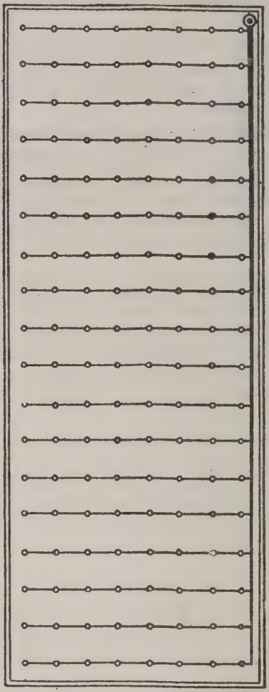
Pipe nipple and hose valve to be 1 inch.

Hose to be 1¼ inch.

Nozzle to be not larger than ½ inch.

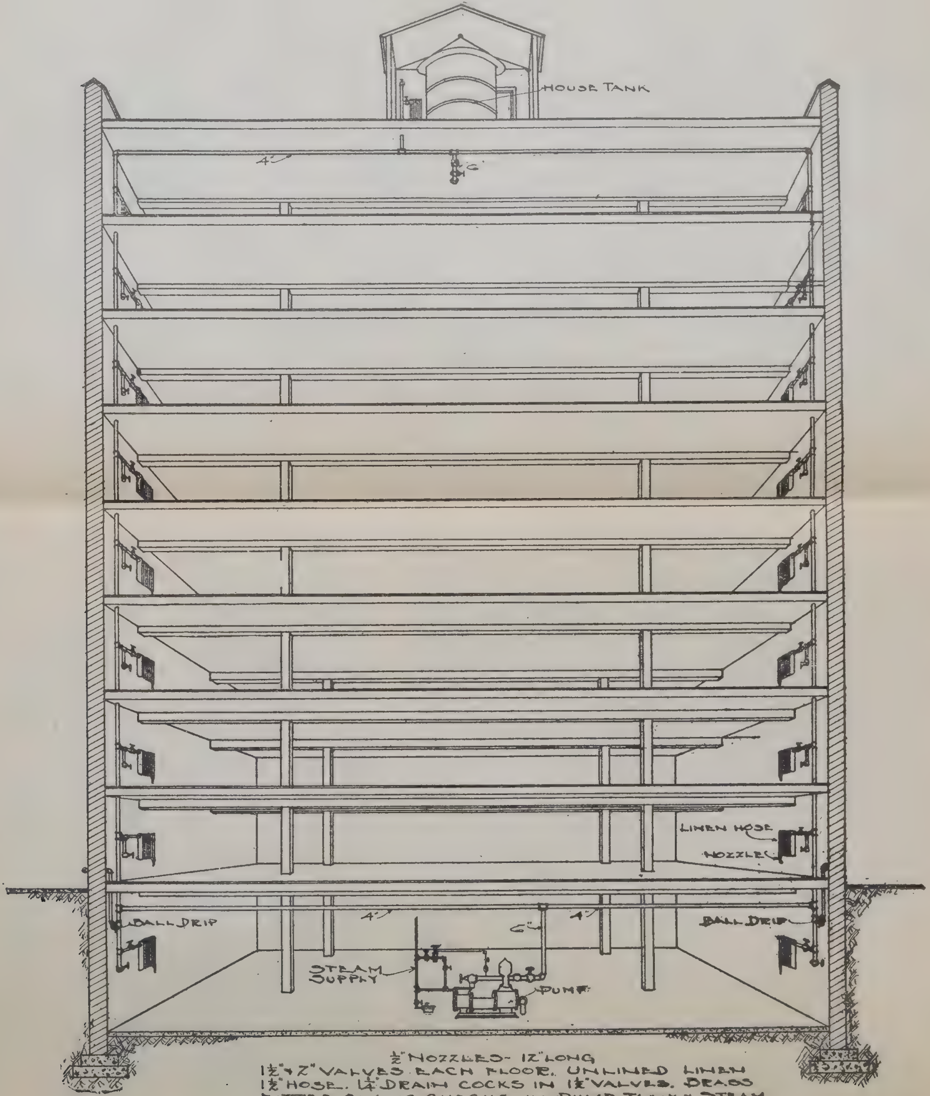
Hose not to be connected to any sprinkler pipe smaller than 2½ inches and never to be attached to a dry pipe system.

General Plan Sprinkler Equipment



End Side-Feed to Automatic Sprinklers.
UNAPPROVED

• shows a Sprinkler. ◉ shows a Riser.


HOUSE TANK
4"
6"
LINEN HOSE
NOZZLE
BALL DRIP
4"
4"
6"
BALL DRIP
STEAM SUPPLY
PUMP

½" NOZZLES – 12" LONG
1½" + 2" VALVES EACH FLOOR. UNLINED LINEN
1½" HOSE. ¼" DRAIN COCKS IN 1½" VALVES. BRASS
FITTED SWING CHECKS IN PUMP, TANK + STEAM
CONNECTIONS. O.S.Y. VALVES IN PUMP AND
TANK CONNECTIONS. NON-CORRODIBLE HOSE RACKS
J.H.B.

TYPICAL ARRANGEMENTS
OF
WATER SUPPLIES, CONNECTIONS AND VALVES
FOR
AUTOMATIC SPRINKLER EQUIPMENTS

NOTE:—The initial source of water supply is from the pressure tanks, or fire pump, followed by water from the gravity tank in case the other sources are exhausted.

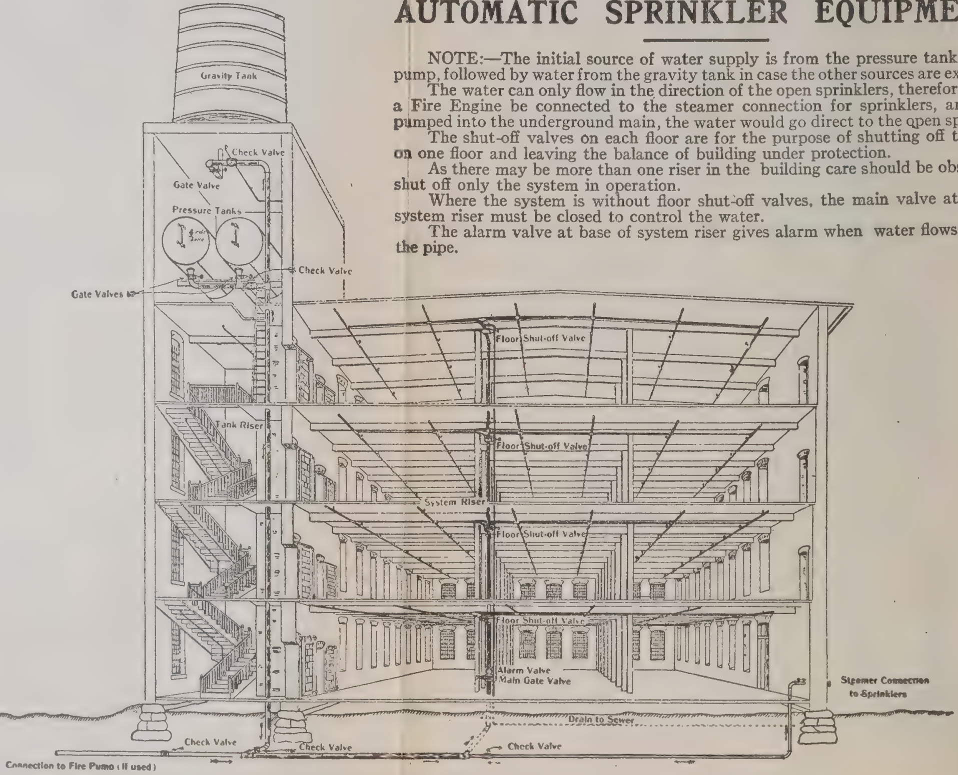
The water can only flow in the direction of the open sprinklers, therefore, should a Fire Engine be connected to the steamer connection for sprinklers, and water pumped into the underground main, the water would go direct to the open sprinklers.

The shut-off valves on each floor are for the purpose of shutting off the water on one floor and leaving the balance of building under protection.

As there may be more than one riser in the building care should be observed to shut off only the system in operation.

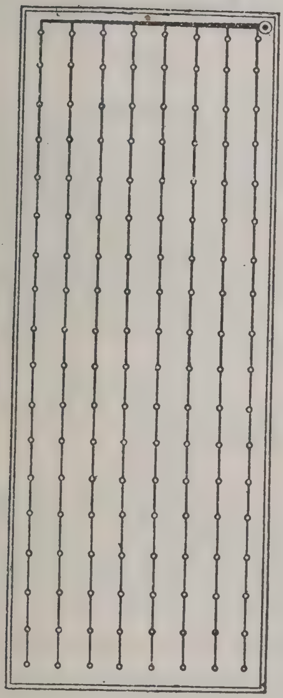
Where the system is without floor shut-off valves, the main valve at base of system riser must be closed to control the water.

The alarm valve at base of system riser gives alarm when water flows through the pipe.


Gravity Tank
Check Valve
Gate Valve
Pressure Tanks
Check Valve
Gate Valves
Floor Shut-off Valve
Tank Riser
Floor Shut-off Valve
System Riser
Floor Shut-off Valve
Floor Shut-off Valve
Alarm Valve
Main Gate Valve
Steamer Connection to Sprinklers
Drain to Sewer
Check Valve
Check Valve
Check Valve
Connection to Fire Pump (If used)

Arrows Show Direction of Water Flow

General Plan Sprinkler Equipment



Across End Feed to Automatic Sprinklers-Long Lines.
UNAPPROVED

∘ shows a Sprinkler. ⊙ shows a Riser.

Pertaining to the Care of Sprinkler Equipments

Inspection

All portions of the equipment should be inspected each day and a report made to some one in authority. Such inspection should include a thorough examination of all tanks, pumps, valves, sprinkler heads, alarms and couplings for city department.

Pressure Tank

Should be kept exactly two-thirds full of water and under an air pressure of not less than 75 pounds. Water gauge valves should be kept closed except when opened to ascertain the amount of water in tanks.

Gravity Tank

Should be kept full of water and free from ice. Ladders should be kept in safe condition.

Fire Pump

Should be kept in working order and operated at least once each week. Steam boiler pressure should never be allowed to fall below 50 pounds. Change recording steam gauge dials daily, date same and keep on file, noting all reasons for discrepancies in record on back of dial. Internal leakage or slip, if exceeding 10 per cent, should be eliminated.

Steamer and Fire Boat Couplings

See that they are not removed or damaged in any way. Keep swivel and threads clean and well lubricated with graphite and oil.

Valves

Make sure that all valves are open. It is desirable to seal them open with light half-inch leather straps and small brass padlocks. Wet system alarm contacts and dry valve contacts should be kept clean and properly adjusted. Maintain an air pressure of not less than 25 pounds nor more than

40 pounds on dry pipe valves. Make certain that dry system is thoroughly drained before it is set up dry. Set valve in absolute accordance with instructions accompanying valve.

Alarms

Should be tested at least twice each week. See that batteries are well charged and that wiring is in good condition.

In General

All stock should be kept 12 inches below sprinkler piping.

Uprights, ceiling blocking, hangers or other obstructions, should not be placed nearer than 12 inches to sprinkler heads.

Piping should not be raised in hangers to avoid belts, pulleys, or other interferences.

Sprinkler heads should never be covered with paint or whitewash; they should be carefully protected with small paper bags when decorating is being done.

Replace all corroded heads with new heads.

Keep all heads free from large accumulation of dirt and dust.

Keep an extra supply, one or two dozen, of sprinkler heads on hand at all times.

When extra heads are installed, maintain the following standard for pipe sizes:

No. of Heads	Pipe Sizes in Inches.
1	¾
2	1
3	1¼
5	1½
10	2
20	2½
36	3
55	3½
80	4
140	5
200	6

Difference in temperature between outside air and air in room, in degrees F.

Be sure to replace all sprinklers, or lines of sprinklers, that have been removed. This fault has caused many serious losses.

Decks or galleries should not exceed 30 inches in width unless sprinkler protection is provided for under side of same. If a gallery or deck 30 inches wide is placed against a wall or partition, a 6-inch clearance should be maintained, and the back of the gallery or deck should be framed in to keep stock clear of the opening.

Do not build fixtures over 5 feet in width. Fixtures over 30 inches in width should be bulkheaded with tight partitions; compartments should not exceed 5 feet deep, 8 feet long and 3 feet high.

Tables more than 30 inches in width and less than 5½ feet in width, under which stock is stored, should be provided with tight upright partitions not exceeding 8 feet on centers; tables wider than 5½ feet should be provided with sprinkler protection underneath.

Never install more than 500 heads on one dry system, because it takes too long for air to clear out of system and allow valve to trip.

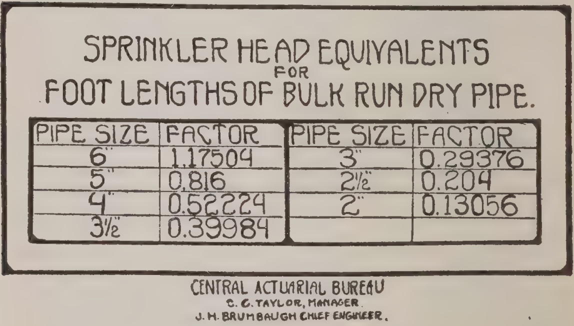
Curtain boards, 12 inches deep, should be placed around all open floor openings; this construction will bank the heat on the ceiling.

When an alarm rings in, do not shut a sprinkler valve until the cause of the alarm is definitely ascertained.

When a partition extending to ceiling is erected, it should be located midway between sprinkler lines and heads; if off center, install extra heads necessary to cover properly.

Never gag a dry valve because of leak; hunt the leak and repair it immediately. Often the leaving of water in a dry system a day or two during warm weather will rust up small leaks.

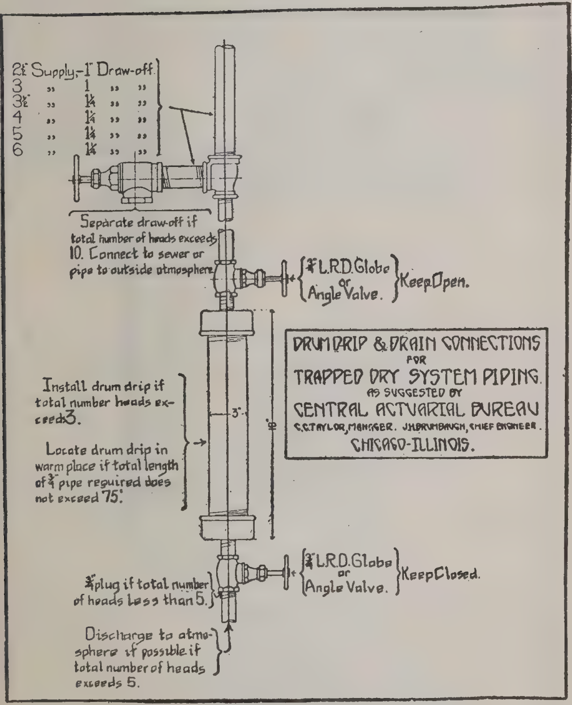
Do not wait for a fire to discover defects which may exist in your protective devices. Give the system careful attention and it may reasonably be expected to perform efficient service.



SPRINKLER HEAD EQUIVALENTS FOR FOOT LENGTHS OF BULK RUN DRY PIPE.

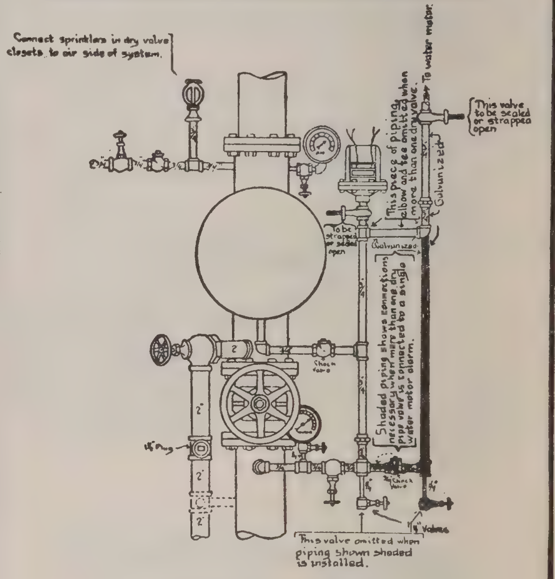
PIPE SIZE	FACTOR	PIPE SIZE	FACTOR
6"	1.17504	3"	0.29376
5"	0.816	2½"	0.204
4"	0.52224	2"	0.13056
3½"	0.39984		

CENTRAL ACTUARIAL BUREAU
C. C. TAYLOR, MANAGER.
J. H. BRUMBAUGH CHIEF ENGINEER.



DRUM DRIP & DRAIN CONNECTIONS
FOR
TRAPPED DRY SYSTEM PIPING.
AS SUGGESTED BY
CENTRAL ACTUARIAL BUREAU
C.C.TAYLOR, MANAGER. J.H.BRUMBAUGH, CHIEF ENGINEER.
CHICAGO-ILLINOIS.

2½" Supply,-1" Draw-off.
3 " 1 " "
3½" " 1¼ " "
4 " 1¼ " "
5 " 1¼ " "
6 " 1¼ " "
Separate draw-off if total number of heads exceeds 10. Connect to sewer or pipe to outside atmosphere.
¾" L.R.D. Globe or Angle Valve. Keep Open.
Install drum drip if total number heads exceeds 3.
Locate drum drip in warm place if total length of ¾" pipe required does not exceed 75'.
3"
18"
¾" L.R.D. Globe or Angle Valve. Keep Closed.
¾" plug if total number of heads less than 5.
Discharge to atmosphere if possible if total number of heads exceeds 5.


Connect sprinklers in dry valve closets to air side of system.
To water motor.
This valve to be sealed or strapped open
This piece of piping, elbow and tee omitted when more than one dry valve.
Galvanized
To be strapped or sealed open
Galvanized
Shaded piping shows connections necessary when more than one dry pipe valve is connected to a single water motor alarm.
2
Check valve
2"
1¼" Plug
2"
2"
Check valve
¾" Valves
This valve omitted when piping shown shaded is installed.

ALARM CONNECTIONS
FOR
DRY PIPE VALVES
AS SUGGESTED BY
CENTRAL ACTUARIAL BUREAU
C.C. TAYLOR, MANAGER. J.H. BRUMBAUGH, CHIEF ENGINEER.
CHICAGO-ILLINOIS.

PIPE SIZES.

National standard requirements recommend installation of but eight sprinklers on a branch line run. It frequently happens that plans show a few lines here and there with nine or ten heads on a branch line run, and it may be necessary in a few cases to lay out an equipment with such a load. All heads in excess of eight should be provided with 2½″ pipe.

Wet systems of 8″ size should not be provided with more than four hundred heads on any one floor.

Where sprinklers are installed in an attic and where such sprinklers are supplied from the same piping which supplies sprinklers under the ceiling of the top floor, the pipe sizes up to and including 3″ should be as follows:

¾″	1 head	2″	14 heads
1″	2 heads	2½″	28 "
1¼″	4 "	3″	48 "
1½″	7 "		

Lines up to and including fourteen in number only should be connected on either side of the supply main or riser. If in a few cases it is found necessary to connect more than fourteen lines all cross main pipe sizes up to and including connection for the fourteenth line should be increased one pipe size and all cross main piping beyond the fourteenth line should carry twenty per cent less heads than the allowable load under pipe schedule. In no case will more than twenty-two branch lines be permitted on a side of a cross main.

FILTRATION PLANTS.

It is sometimes thought that the chief reason for installing filters is to protect the heath of those using the water for drinking purposes. Most filters installed in residences, apartment buildings, hotels and similar buildings are either installed for the purpose of cleanliness or to protect the plumbing system, or both. Where a water supply is turbid or contains floating particles of any kind, there is continuous trouble with valves, cocks, etc. Where the water is very bad, lines may even become stopped up. All this is entirely prevented by filtration. At the same time there is no piece of equipment put into a building where people live that gives more satisfaction than a filter by insuring at all times a supply of clear, clean, bright water.

Filters can be obtained in sizes from that suitable for a small dwelling up to any capacity to take care of the largest building. Filters are not difficult to install, but there are certain precautions that should always be taken. The first thing to be considered is the selection of a proper size filter. Sometimes this is done by taking meter readings over a period of a month and averaging this to find how much water is used per hour. This is not a proper way because the use of water in any such building is never uniform. On the contrary, there are periods when almost no water is used, and other periods when the consumption is very high. The filter should be selected with a view to having capacity to take care of the maximum flow.

The filter may be located in any convenient place. The supply line to the sill cocks should be taken off before the filter, as there is no use of filtering water used for sprinkling lawns and such purposes. All water used inside the building should, however, pass through the filter. The only satisfactory type of filter for such service is the sand filter, and this type of filter will give excellent service for years without any repairs or renewals if properly installed and taken care of. The smaller capacities of filters are usually constructed with a cast iron shell as shown in illustration A. In the larger capacities the shell is commonly of steel as shown in illustration B. Under certain conditions the desired capacity should not be installed in a single unit, but there should be provided a battery of three units as shown in illustration C. Particular consideration should be given to determine whether one or three units is desirable in each case. There are several causes that may make an installation of three units preferable or necessary. One is that of space. Frequently it is necessary to install filters in a narrow passageway where a battery of three can be placed along the wall easily, whereas a single unit would be too large and would close the passage. Again, there must be considered cleaning the filter. In the sand filter this is done by reversing the flow of water.

When the filter is filtering the water enters at the top and passes down through the bed of sand, the mud or other suspended impurities being retained on top of the sand. At certain intervals, or when the filter becomes clogged with accumulated sediment, this must be removed, which is done as mentioned above by reversing the flow of water. When washing the water enters at the bottom of the filter, passes up through the sand bed and overflows at the top, carrying with it

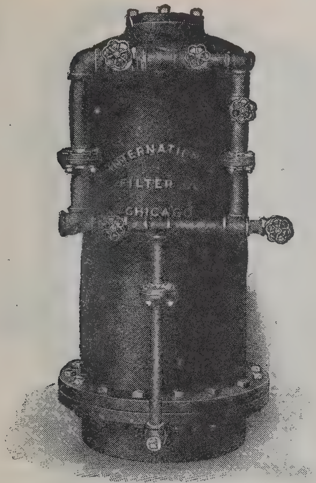


Illustration A

the mud or other material removed. It is necessary when the filter is being washed to have a stronger flow of water than the filter will handle when filtering. If the wash flow is not sufficient the sand bed will not be thoroughly loosened up and scoured out. In good practice the flow when washing must be three times that when filtering; consequently when the supply line is only large enough to carry the required flow when filtering, it is necessary to install the filter in three units so they can be washed one at a time. In many cases the water being filtered is so muddy or otherwise so bad that if used in its raw condition for washing, dirt would be left all through the filter bed. To meet this condition filters are installed in a battery of three as shown in illustration C. With this installation water can be drawn through any two filters to wash the third, which is thus perfectly cleansed with filtered water.

The inlet, outlet and waste openings of the filter are marked in the illustration. The waste line must always be carried full size to sewer. If this waste discharge is restricted it will interfere with proper washing of the filter. For the same reason this waste discharge should be as short and straight as possible.

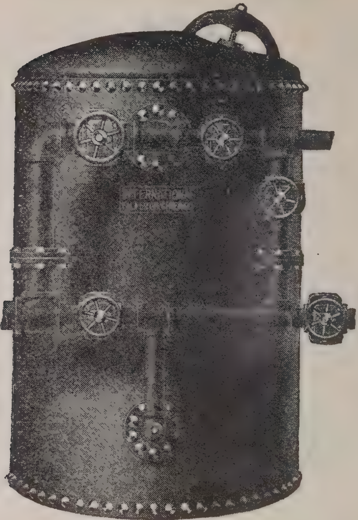


Illustration B

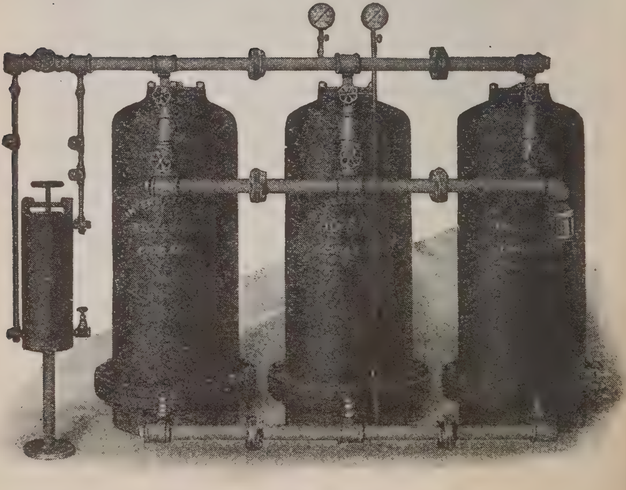


Illustration C

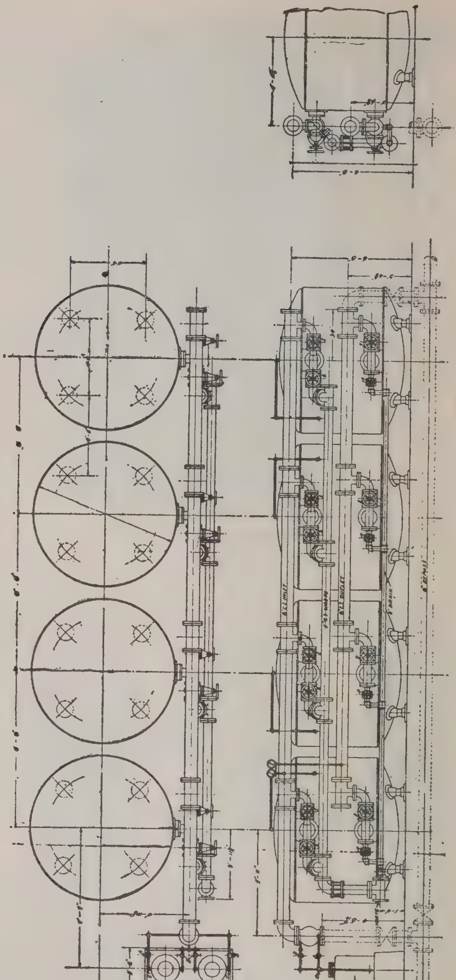
A coagulant feeder as shown to the left of the three filters in illustration C. The waste line must always be carried full size to sewer. If this waste discharge is restricted it will interfere with proper washing of the filter. For the same reason this waste discharge should be as short and straight as possible.

A coagulant feeder as shown to the left of the three filters in illustration C, is always supplied with a sand filter. In this a small amount of alum is placed which is automatically fed to the water. Some people have the mistaken idea that this alum remains in the water. This is not the case. On the contrary, if it remained in the water it would not do its intended work. It acts on the mud and other impurities in the water and separates itself out in solid form so that it is removed with the mud remaining in the filter on top of the sand. In many or most cases it is impossible to obtain clear water without the use of alum.

The loss in pressure of the water passing through a sand filter is very small. When the filter is perfectly clean this loss seldom amounts to as much as a pound. As mud deposits in the filter thus clogging it this loss in head increases. In good practice the filter is washed once every twenty-four hours or oftener if the water being filtered is so extremely bad that the loss in pressure due to mud depositing on the sand causes a pressure drop of over five pounds. This latter condition, however, is practically never met with in building work. A filter is not like a piece of pipe, the capacity of which is determined by the amount of water that can be forced to flow through it with the pressure available. If water is forced through the sand bed too rapidly it will carry sediment with it and the filtered water will not be clear and bright. In good practice the area of the sand bed is such that at the maximum rate of operation the flow of water will not exceed three gallons per square foot per minute, and if the water is very bad, or other conditions are unfavorable, the rate should not be over two gallons per square foot.

Typical Installation of a Filtering Plant Ready for Pump Connections.

When installing filters in a manufacturing plant to purify water for drinking supply or factory purposes, the various points referred to above must be taken into consideration in the same way. There is no difference



Layout of Filtering Plant

in the construction, operation or method of connecting up the filters for factory service from that used in other buildings. The quantity of water used for manufacturing varies greatly in different plants, and frequently considerably exceeds the amount used in residence buildings, consequently larger filters or a greater number of units may be used. In illustration D is a cut of a battery of four filters as furnished by the International Filter Co. to a large steel mill. This cut shows the filters installed with a by-pass on the general supply line. In this particular case the supply line and by-pass is under ground or under the floor. It may, however, be just as well run above the filters under the ceiling whenever desired. The supply line to the filters may be from pump, city main or other source, and may be run in any convenient manner. If supply is taken from a pump it is excellent practice to put a large sized air chamber on the supply line between the pump and filter so as to eliminate pulsations or reduce them to a minimum. The discharge from the filter may be led back into the general supply main as shown, or it may lead to a storage tank of any desired construction. The waste connection from filter to sewer should always be short and straight as possible, and must be carried full size the same as the waste opening on the filter. It is excellent practice to bring the sewer opening close to the filters and instead of making a closed connection from the filter waste to leave this connection open; that is, the waste discharge pipe from the filter should be cut off a few inches above the sewer opening, allowing the waste water to fall into the sewer. This permits the filter operator to see the waste water when washing the filters and thus most conveniently judge when the filters have been sufficiently washed.

The Use of Water Softeners

All mechanical engineers concede that hard water is a detriment to boilers and piping. When analyzed it is found to contain certain minerals that are destructive to iron and steel, which as a consequence shortens the life of both boiler and piping. I therefore advocate the use of a water softener for both high and low pressure boiler feed, as well as for domestic use.

A water softener prevents scaling and does away with the unnecessary labor of using boiler compounds such as are generally used daily by engineers everywhere. Do away with this nuisance!

Any engineer having anything to do with power plants where boilers are used can safely recommend a water softener of good type such as the "Permutit."

Boiler scale will not be found where soft water is used.

Make boiler washing a thing of the past by recommending a good softener.

"PERMUTIT" WATER SOFTENER

Permutit looks something like coarse sand, and its water softening properties are utilized by placing it in a tank and allowing the hard water to percolate through it. After it has abstracted its full quota of hardness, the water is shut off and the softener regenerated with a solution of common salt in water. The sodium of the salt replaces the lime and magnesia and the softener is brought back to its exact original condition ready to soften another quota of hard water.

The regeneration cycle is ordinarily arranged to take place at night when plants are closed, or two softeners are placed parallel to give 24-hour continuous service.

Water softened by Permutit differs from that attained by any other method, in that it is absolutely soft, by which is meant the hardness is reduced to zero. In addition it is clear, clean and ideal, not only for drinking but for the most exacting industrial uses. There is no possibility of "over dosage" as in chemical plants for no chemicals are added to the water and no expert supervision is required even when the hardness of the raw water varies over a wide range. Operating and maintenance costs are lower per grain of hardness removed than for any other method of softening water, while the results obtained can only be compared with those that might be achieved with distilled water.

With the increasing scarcity of coal due to increased consumption and congestion of transportation and with the generally higher cost of fuel it is the duty of every one to investigate every possible way that fuel is wasted and how the wastage may be prevented. There is no doubt that the general consideration of burning the coal efficiently in the boiler furnace comes first, but the heating surfaces of the boiler must also be kept clean, otherwise the heat produced in the furnace cannot be utilized fully. Every engineer and fireman knows these things, but they have not been watched carefully in the past owing to the great wealth of natural resources. The time has come, however, when ways must be changed and every pound of coal made to count.

In boiler plants Permutit guarantees complete elimination of scale, sludge and mud from the interior of boilers and connections, and will do away with boiler cleaning altogether.

For Use in Laundries.

Laundries seeking the means of producing sweet-smelling, white, soft wash, at minimum washing costs, find the solution of their problem in "Zero-water" the unfailing consistent delivery of Permutit apparatus, and in Permutit washing methods, developed and installed by our laundry experts.

No laundry doing the average class of work need use more than 12 pounds of soap per $100.00 worth of work, with similar low soda consumption. Permutit equipped laundries in every state are washing with such low quantities of supplies every day; many use less. The average laundry owner pays for his Permutit Softener from the dividends it pays in a little over sixteen months' operation. Considering that he is washing in water containing no hardness, iron, or suspended matter, water that can deposit no "lime soap," that is not astonishing; and the absence of the "lime soap" is the reason behind the white, soft, sweet-smelling wash.

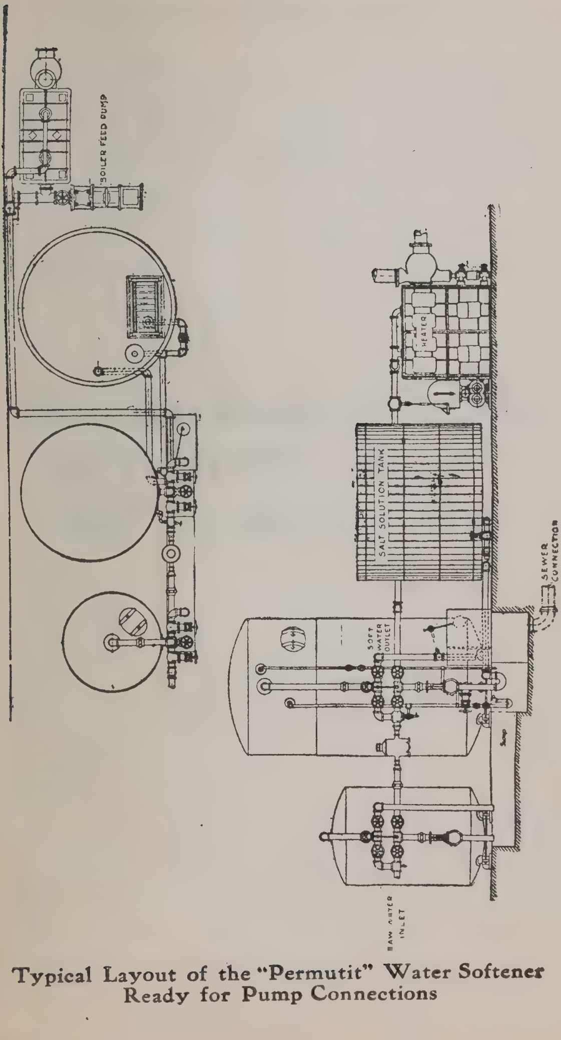
Investment and Operating Costs.

The comparative investments in different water-softening systems depend entirely on the composition of the water. Lime.soda plants remain fairly constant in cost with varying compositions, whereas exchange-silicate plants increase in size and cost with increase of hardness in the raw water. Cost of treatment depends also on the water composition and the proportion of temporary and permanent hardness. The cost of lime treatment alone is about one-third to one-half the cost of the corresponding salt for regeneration, but, as pointed out in the foregoing, the cost of the soda-ash treatment is about three times the cost of salt for regeneration. In conclusion, a typical case will be analyzed to determine the actual savings that would result from installing a water-softener without reference to the type used. Take a water of the following composition (same as water in the Bridgeport installation mentioned above):

			Grains Per Gal.
Total hardness,	as $CaCO_3$ =	130 p.p.m. =	7.7
Calcium hardness,	as $CaCO_3$ =	80 p.p.m. =	4.7
Magnesium hardness,	as $CaCO_3$ =	50 p.p.m. =	3.0
Alkalinity,	as $CaCO_3$ =	80 p.p.m. =	4.7
Temporary hardness,	as $CaCO_3$ =	80 p.p.m. =	4.7
Permanent hardness,	as $CaCO_3$ =	50 p.p.m. =	3.0

Assuming a boiler plant of 3000 hp., consisting of ten boilers with no returns using 12,000 gal. (45,400 l.) per hour raw feed water, the first cost including foundations and connections would be about $20,000. The cost of operation for chemicals would be about 3 cents per 1000 gal. (3785 l.). With a coal consumption of 1 pound (0.45 kg.) per 8 pounds (3.62 kg.) of water evaporated, the average daily consumption of coal would be about 150 tons. Assuming a price for coal at $4 per ton and a saving of 5 per cent for fuel, then the fixed and operating charges of water-softener would be.

	Per Year
288,000 gal. per day × 3 cents = $8.64..... =	$3,150
Labor of operation .... =	500
Interest and depreciation, at 10 per cent... =	2,000
Total	$5,650


BOILER FEED PUMP
HEATER
SALT SOLUTION TANK
SEWER CONNECTION
SOFT WATER OUTLET
Sump
RAW WATER INLET

Typical Layout of the "Permutit" Water Softener Ready for Pump Connections

HANDY INFORMATION OF ALL KINDS FOR THE STEAM FITTER

Estimating for Steam and Hot Water Heating

The successful heating contractor or estimator must first of all know how to figure the correct amount of radiation required in each room,—must take in consideration the location of the room, as a certain percentage of radiation must be added to rooms having north or east exposure as winds from those directions are always cold and the rooms hard to heat. After he has added up the total radiation he must decide on the size of the boiler. Due to condensation in mains, risers and branches, an additional amount of radiation must be added to the sum of total square feet of radiation of the radiators. For a large job where a steel tubular boiler is best adapted it is customary to add from 33⅓%,—at least,—for smaller boilers, and from 20% to 22% for boilers of 14000 or more square feet of radiation. After the total square feet of radiation is determined the size and number of boiler can be obtained from a boiler manufacturer's catalogue. When using a cast iron boiler a bigger percentage has to be added. For instance, if selecting a cast iron boiler, as high as 92% must be added to the capacity of the boiler. This applies to boilers from 1000 square feet to 14000 square feet. How to figure the radiation required in certain rooms can be found in Johnson's Handy Manual.

The estimator must carefully study the architect's plans and specifications from which he must, if amount of radiation for each room is given on the plans, make a check in order to see that the amount given is correct. This is a safe way and should always be lived up to, as the heating contractor is held responsible for the success of the heating system.

In estimating the cost of a heating job the only sure way is to figure the cost of each item separately; for instance, so many square feet of different makes of cast iron radiation cost a certain sum; the boiler, whatever the kind or make, costs when erected complete, including foundation and bricking-in if a tubular boiler, a certain sum. Then we must figure the cost of breeching erected, and covering with asbestos if it is to be a cast iron boiler. Next comes the amount in feet of different sizes of pipes, then valves and fittings of all kinds, including pipe hangers, sleeves and floor and ceiling plates. Even the bronzing and painting of radiators should be taken into consideration. If the mains and branches are to be **insulated** the cost of the covering must also be noted. In fact, everything, no matter how small the item might be,—should be charged, as during a year these small items amount to quite a respectful sum of money. After the quantities are determined consult your price lists and get the net cost of the different materials.

The judgment of the estimator must be the guide, however, in considering the known difficulties that will have to be overcome in estimating labor costs.

No job can be figured by rule; every job is different and requires a separate estimate. It is good and advisable for the estimator to have a record of previous jobs, both the estimated cost and the actual cost as shown by his books, and refer to this record when figuring a new job. When the estimate of the actual cost is completed 10% must be added as the overhead expense and another 10% or more as profit. Do not forget to add either of the two above items.

Every heating contractor, big or small, should have a system and not go at it in a haphazard way. He should open an account for every job, charge up everything sent to the job, whether the article be big or small, and credit the job for everything returned. Also charge up the actual time of the mechanics and helpers. This is, I am sorry to say, often neglected by smaller contractors, and as a consequence they do not know how much or if any profit was made on the job. Many contractors have told me it is too much trouble and requires regular bookkeeping to keep such a record, but after they have once tried it on a job they are surprised to see how little work is required to keep a complete "tab" on the expenses and what a satisfaction it is to know the actual cost.

APPROXIMATE COST OF HEATING JOB PER SQUARE FEET OF RADIATION

Several estimators and contractors have made comparisons by dividing the contract price of a job with the square feet of cast iron radiation, and it has been found that a steam heating installation in a flat or apartment building can be made complete with boiler, radiators, piping, and everything at a cost of $1.25 to $1.50 per square foot of radiation, and for a hot water job the cost is approximately $1.25 per square foot.

In a residence, on account of the arrangement of the rooms, a great deal more piping and labor is required per square foot of radiation than in a flat building. It has been found that the cost is about 20% in excess of figures quoted above, both for steam and hot water jobs.

These figures are good for and should be used only to ascertain the approximate cost of a job, when you know the square feet of radiation. I strongly advise that no contracts be signed for a job, the price of which is arrived at by using a system of **So Much Per Square Foot of Radiation,** as sometimes it will work, but most times will not.

In estimating the amount of materials required for bricking fire box and tubular boiler pages 54-56 of this book will be of great assistance. For figuring boiler sizes for direct radiation see pages 39 and 40, and for figuring radiation see pages 71-74.

Tables for mains and branches for steam and hot water will be found on pages 35-39, and riser diagram and sizes on page 166.

Mains and branches for vacuum and vapor heating on pages 46 and 47, and vacuum pump sizes on page 48.

Other valuable tables can be found by consulting the general index.

Useful Information

Steam.

A cubic inch of water evaporated under ordinary atmospheric pressure is converted into 1 cubic foot of steam (approximately).

The specific gravity of steam (at atmospheric pressure) is .411 that of air at 34 Fahrenheit, and .0006 that of water at same temperature.

27,222 cubic feet of steam weigh 1 pound; 13,817 cubic feet of air weigh 1 pound.

Locomotives average a consumption of 3,000 gallons of water per 100 miles run.

The best designed boilers, well set, with good draft, and skillful firing, will evaporate from 7 to 10 lbs. of water per pound of first-class coal.

In calculating horse-power of tubular or flue boilers, consider 15 square feet of heating surface equivalent to one nominal horse-power.

On one square foot of grate can be burned on an average from 10 to 12 lbs. of hard coal, or 18 to 20 lbs. soft coal, per hour, with natural draft. With forced draft nearly double this amount can be burned.

Steam engines, in economy, vary from 14 to 60 lbs. of feed water and from 1½ to 7 lbs. of coal per hour per indicated H. P.

Rules for Calculating Speed of Pulleys.

1. The diameter of the driver and driven being given, to find the number of revolutions of the driven:

Rule. Multiply the diameter of the driver by its number of revolutions, and divide the product by the diameter of the driven; the quotient will be the number of revolutions.

2. The diameter and the revolutions of the driver being given to find the diameter of the driven, that shall make any given number of revolutions in the same time:

Rule. Multiply the diameter of the driver by its number of revolutions, and divide the product by the number of revolutions of the driven; the quotient will be its diameter.

3. To ascertain the size of the driver:

Rule. Multiply the diameter of the driven by the number of revolutions you wish to make, and divide the product by the revolutions of the driver; the quotient will be the size of the driver.

Doubling the diameter of a pipe increases its capacity four times.

Double riveting is from 16 to 20 per cent stronger than single.

One cubic foot of anthracite coal weighs about 53 pounds.

One cubic foot of bituminous coal weighs from 47 to 50 pounds.

One ton of coal is equivalent to two cords of wood for steam purposes.

A square foot of uncovered pipe, filled with steam at 100 pounds pressure, will radiate and dissipate in a year the heat put into 3,716 pounds of steam by the economic combustion of 398 pounds of coal. Thus, 10 square feet of bare pipe corresponds approximately to the waste of two tons of coal per annum.

To determine necessary surface in square feet for aspirating coil in ventilating flue divide air to be moved per hour by .950 for steam radiation, and .600 for water radiation.

To reduce Fahrenheit temperature to centigrade subtract 32 from Fahrenheit reading, multiply by 5 and divide by 9.

To reduce centigrade to Fahrenheit multiply centigrade reading by 9, divide by 5 and add 32.

One H. P. will take care of 75 to 100 square feet of direct radiation.

In one ton of soft coal there are 11,000 B. T. U.

150 cubic feet of air require combustion of one pound of coal.

3 barrels of fuel oil—a ton of soft coal and has 19,200 B. T. U.

Fuel oil weighs 8 pounds to the gallon.

One gallon fuel oil per hour will heat 1000 square feet of direct radiation.

One foot of gas will heat a gallon of water per hour in the right kind of hot water heater to 185°.

There are about 10,000 feet of gas in a ton of average soft coal.

One mile, 5,280 feet.

Increasing the Efficiency of Hot Water Heating Systems.

In case it is necessary to increase the efficiency of a hot water plant—to give it increased radiation, the experience of the author of this book will prove invaluable.

In an open tank job he says the radiation may be increased 25% by disconnecting the overflow and vent pipes and by removing the gauge glass and plugging up all openings, making a completely sealed job. Then get the best relief valve to be had and connect in the supply main at a convenient place. In this way hot water radiation can be made as efficient as steam radiation.

The use of crosses or bull-headed tees in connection with either steam or hot water systems is to be avoided. There are cases, however, where their use is entirely proper as in feeding or blowing out boilers.

By all means avoid the use of traps on mains and branches as they make noisy jobs called water-hammering. Other chapters in this book show how to further avoid this nuisance.

RADIATOR DECORATION.

This feature, considered until recently to be one of the minor details, has been found to be an extremely important factor in the operation of a heating system. In order to establish this point, we have conducted exhaustive experiments in the decorating of radiators with paints and bronzes of various kinds and colors. These experiments have proven conclusively the superiority of Enamel Paints over the customary aluminum, gold or copper bronze finish, and following in a record of tests made, showing the relative efficiency as a condensing medium between enamel paints and aluminum, gold or copper bronze. The same radiator was used for all tests, which were made in the order given:

1. Cast Iron Radiator—Bare as received from the foundry, 100%.
2. Cast Iron Radiator—Coated with Aluminum Bronze, 78%.
3. Cast Iron Radiator—Three Coats of White Enamel Paint, 102%.

4. Cast Iron Radiator—Coated with Aluminum Bronze, 78%.
5. Cast Iron Radiator—Three Coats of Green Enamel Paint, 101%.
6. Cast Iron Radiator—Three Coats of Black Enamel Paint, 101½%.

Use Enamel Paint.

Thus it will be seen that while the bronze finish reduces the condensing capacity of the bare cast iron radiator 22%, the application of enamel paint of any color, having as a base a pure varnish made of resinous gums, produces a radiating surface that slightly exceeds in efficiency that of the bare radiator. It makes no difference if the enamel paint is applied over the bronze, or the bronze over the paint, the ultimate result being dependent entirely upon the last covering given the radiator.

We find in our experiments that color has no effect whatever; it does not matter whether the radiator is covered with white, black, red, blue, green or yellow enamels, the effect on radiant heat is the same. We have also covered radiators with four coats of white enamel, one on top of the other, and up to the last coat the emission of heat gradually increased. Putting on five or six coats does not increase the emission; nor does it seem to diminish it.

From these facts and figures our deductions are that decreased efficiency produced by bronze or other covering, using zinc as a base, is due to the galvanizing or non-conducting effect caused by its application, while paints of any color, having a large percentage of pure varnish made from resinous gums, create a surface of high conductive qualities, making heat transmission much more rapid.

Color Radiators to Match Rooms.

Since these enamel paints can be used in practically any color with equally good results, they can be selected so that the radiators may be of a color corresponding to the rooms in which they are to be placed, and thus mitigate, to a great extent, the heretofore unattractive appearance that has frequently been the cause of complaint.

Radiators.

The use of Hot Water Type Radiation with the inlet valve at the top of the radiator is strongly recommended, because of freer and more positive circulation as well as greater ease of control.

A Noiseless System.

If properly installed, all radiators and return mains are thoroughly drained, and as there is no steam in the return pipes, which are open to the atmosphere at all times, a water hammer is impossible, and an absolutely noiseless system is assured. This is an important feature, as all are familiar with the distressing noises in steam pipes caused by air binding and the contact of steam with cold water.

Trouble from Improper Turning of Steam Radiator Valves.

Still another source of trouble and loss of water from the boiler comes in the manner in which radiator valves are handled, especially on the two pipe system, and this is when it is desirable to close off the heat: The inlet valve is closed, while the return valve may be left partly or entirely open, thus allowing condensation to back up from some other source and thus storing up a considerable amount of water in the radiator, to the detriment of the boiler, because this water is not intended to accumulate in any part of the system above the return pipes, but fall by gravitation to the boiler. It will therefore be seen that on two pipe radiators, both valves must be left wide open or both perfectly closed, in order to have the apparatus operate in a proper manner. The same applies to a one pipe system as well.

Usual Inside Temperatures Specified.

Public Buildings	68°-72° F.
Factories	65° F.
Machine Shops	60°-65° F.
Foundries, Boiler Shops, etc.	50°-60° F.
Residences	70° F.
Bath Rooms	85° F.
Schools	70° F.
Hospitals	72°-75° F.
Paint Shops	80° F.

"B. T. U." IN COAL.

The Heat contained in coal is expressed in British Thermal Units (abbreviated B. T. U.); a B. T. U. being the quantity of heat required to raise one pound of water one degree Fahrenheit.

The "B. T. U. Commercial" indicates the number of B. T. U. contained in one pound of coal as delivered including the moisture which it contained at the time the sample is taken. This figure is useful for comparing the quantity of heat in the various coals as received.

The "B. T. U. per pound Dry" indicates the number of B. T. U. contained in one pound of coal after all moisture has been baked out of it, and is an indication of the maximum possibility of heat value of the particular sample of coal.

"Percent Moisture" and "Percent Ash" represent respectively the amount of moisture and ash contained in the coal expressed in percentage of the weight of the coal as received.

"Net B. T. U. for 1 cent" represents the amount of heat that 1 cent will buy, and is obtained by multiplying the "B. T. U. Commercial" by 2,000 (to ascertain the number of B. T. U. in a ton) and dividing this product by the price of the coal per ton (expressed in cents) plus 50%, the percentage of ash (representing the cost of carting away the ashes from one ton); for example, the net B. T. U. for 1 cent is figured as follows:

11,700 Commercial B. T. U. per pound.
2,000 pounds per ton.

23,400,000 B. T. U. per ton.
.50 cost per ton removing ash.
.08 per cent of ash in coal as delivered.

.0400 cost of removing ash per ton of coal delivered.
230 cents price per ton (expressed in cents).
4 cents cost of removing ash.
---
234 cents 23,400,000 divided by 234 equals 100,000 the net B. T. U. for 1 cent.

As the "Net B. T. U. for 1 cent" takes into account the various conditions of moisture, ash, price and heat, it is the most useful figure to use in comparing the value of different coals as received.

A gallon of water (U. S. Standard) weighs 8⅓ pounds, and contains 231 cubic inches.

A cubic foot of water weights 62½ pounds, and contains 1,728 cubic inches, or 7½ gallons.

Each Nominal Horse-Power of boilers requires 1 cubic foot of water per hour.

In calculating horse-power of steam boilers, consider for tubular or flue boilers 15 square feet of heating surface equivalent to 1 horse-power.

Condensing engines require from 20 to 25 gallons of water to condense the steam evaporated from one gallon of water.

To find the pressure in pounds per square inch of a column of water, multiply the height of the column in feet by .434. (Approximately, every foot elevation is called equal to one-half pound per square inch.)

To find the capacity of a cylinder in gallons. Multiply the area in inches by the length of stroke in inches will give the total number of cubic inches; divide the amount by 231 (which is the cubical contents of a gallon in inches), and the product is the capacity in gallons.

Ordinary speed to run pumps is 100 feet of piston per minute.

To find quantity of water elevated in one minute running at 100 feet of piston per minute. Square the diameter of water cylinder in inches and multiply by 4. Example: Capacity of a five-inch cylinder is desired; the square of the diameter (5 inches) is 25, which, multiplied by 4, gives 100, which is gallons per minute (approximately).

To find the diameter of a pump cylinder to move a given quantity of water per minute (100 feet of piston being the speed), divide the number of gallons by 4, then extract the square root, and the result will be the diameter in inches.

To find the velocity in feet per minute necessary to discharge a given volume of water in a given time, multiply the number of cubic feet of water by 144, and divide the product by the area of the pipe in inches.

To find the area of a required pipe, the volume and velocity of water being given, multiply the number of cubic feet of water by 144, and divide the product by the velocity in feet per minute. The area being found, it is easy to get the diameter of pipe necessary.

The area of the steam piston multiplied by the steam pressure, gives the total amount of pressure exerted. The area of the water piston, multiplied by the pressure of water per square inch, gives the resistance. A margin must be made between the power and the resistance, to move the pistons at the required speed; usually reckoned at about 50 per cent.

Every pound of coal requires a definite amount of air to burn it. It therefore requires ten times as much air to burn properly one hundred pounds of coal as it does to burn ten, and so on. Don't try to do what is impossible; a boy may sometimes be made to do a man's work, but a small chimney cannot possibly do the work of a large one.

The Boiling Point of Water.

Water boils at different temperatures, according to the elevation above the sea level. In New York water boils practically at 212 degrees Fahrenheit; in Munich, Germany, at 209½ degrees; in the City of Mexico, at 200 degrees, and in the Himalayas, at an elevation of 18,000 feet above the level of the sea, at 180 degrees. These differences are caused by the varying pressure of the atmosphere at these points. In New York the whole weight of the air has to be overcome.

In Mexico, 7,000 feet above the sea, there is 7,000 feet less of atmosphere to be resisted; consequently less heat is required and boiling takes place at a lower temperature.

Under no consideration should ¾-inch pipe be used in any kind of hot water **heating systems. Use 1-inch or larger in all cases.**

Condensed Rules for Calculating Boiler Horse-Power.

Under Favorable Conditions. A flue boiler will evaporate 2 lbs. of water per hour per square foot of heating surface. Now, as the evaporation of 30 lbs. of water per hour into steam of 70 lbs. gauge pressure, when feed water has a temperature of 100° F., constitutes a horse-power, then each 15 square feet of heating surface in this type of boiler, with good coal and good draft, will generate a horse-power.

Tubular and water tube boilers can be made to furnish a horse-power for each 12 feet of heating surface. Locomotive boilers will develop 1 horse-power for each 8 square feet of heating surface. Under average conditions, with feed water at 100° F., and steam at 70 lbs. gauge pressure, and 3,000 lbs. of water be evaporated in one hour in any boiler above mentioned, then 3,000 ÷ 30 = 100 horse-power developed by that boiler. In actual practice, however, the conditions must be reduced to the standard given, as follows:

Rule—Multiply the total heat of steam at pressure carried (minus temperature of feed water) by the lbs. of water evaporated per hour and divide by 1,100 (British thermal unit), the quotient will be the lbs. of water evaporated with feed water at 100° F. and a steam pressure of 70 lbs. Now ÷ again by 30 = the horse-power developed.

Problem—The steam pressure being 90 lbs. and feed water 210° F., and 3,400 lbs. of water being evaporated per hour, what is the horse-power? Referring to steam table we find that 90 lbs. gauge pressure (or 105 lbs. absolute pressure) contains 1,182° above 32° or 1,182 + 32 = 1,214. Then 1,215 — 210 = 1,004°, and 1,004 × 3,400 = 3,413,600. This ÷ 1,100 = 3,075 lbs., which would have been evaporated under standard conditions with the same amount of heat, and 3,075 ÷ 30 = 102 horse-power developed.

The horse-power of boilers is best defined by the heating surface of a boiler, and is different according to their construction. A tubular boiler will give one horse-power to every 15 square feet of heating surface; a flue boiler every 12 square feet, and a cylinder boiler 10 square feet gives one horse-power. There is no standard law governing the horse-power of steam boilers, but this rule is adopted by most experts as a fair rating.

One cubic foot of water evaporated per hour = 2 nominal horse-power.

7½ pounds of coal consumed per hour will evaporate about 1 cubic foot of water = 2 horse-power.

1 square foot of grate will consume on average 12 pounds of coal per hour = 1⅗ horse-power.

?

Engine Horse-Power.

All calculations to find the horse-power of an engine are necessarily only approximate, as they are modified more or less by the factors or friction in the moving parts, condensation, quality of lubricants, amount of load, etc.

The unit of power is the horse-power, and was first calculated by Watt, that prince of inventors in steam enginery; and after numerous experiments, Watt estimated the power of a good, average draught horse to be that which could lift 33,000 lbs. one foot high in a minute, 550 lbs. in one second, or 1,980,000 lbs. in an hour. Hence we have the horse-power factor, 33,000 lbs.

Rule to Find Horse-Power of an Engine.

Area of piston in inches, multiply by pressure per square inch, multiply by speed of piston in feet per minute, and that product divided by 33,000.

$$\text{H. P.} = \frac{\text{P-L-A-N}}{33{,}000}$$

P—Pounds pressure per square inch.
L—Length of stroke in feet.
A—Area of piston in square inches.
N—Number revolutions per minute.

The pressure per square inch should be the mean pressure throughout the stroke exerted on the piston, which can be found by attaching an indicator to the engine. The result will be what engineers term, indicated horse-power.

For the net effective horse-power, deduct from the above about one-quarter for friction of the working parts.

When the indicator is not used, and in the calculation the boiler pressure is substituted for the mean effective pressure, deduct from the result obtained from 40 to 60 per cent for loss by condensation and friction of steam in pipes and passages, decrease of pressure in cylinder due to expansion, back pressure of exhaust, and friction of the working parts.

For engines from 20 to 60 horse-power, an average of 50 per cent may be deducted; for smaller engines more.

The mean pressure in the cylinder when cutting off at

¼ stroke equals boiler pressure multiplied by .597
⅓ stroke equals boiler pressure multiplied by .670
⅜ stroke equals boiler pressure multiplied by .743
½ stroke equals boiler pressure multiplied by .847
⅝ stroke equals boiler pressure multiplied by .919
⅔ stroke equals boiler pressure multiplied by .937
¾ stroke equals boiler pressure multiplied by .966
⅞ stroke equals boiler pressure multiplied by .992

Horse Power of an Engine.

A equals Area of piston in square inches.
P equals Mean pressure of the steam on the piston per square inch.
V equals Velocity of piston per minute in feet.

$$\text{Then H. P. equals } \frac{a \times p \times v}{33000}$$

The mean pressure in the cylinder when cutting off at
¼ Stroke equals boiler pressure × .597
⅓ Stroke equals boiler pressure × .670
⅜ Stroke equals boiler pressure × .743
½ Stroke equals boiler pressure × .847
⅝ Stroke equals boiler pressure × .919
⅔ Stroke equals boiler pressure × .937
¾ Stroke equals boiler pressure × .966
⅞ Stroke equals boiler pressure × .992

To find the weight of the rim of the fly wheel for an engine:

$$\frac{\text{Nominal H. P.} \times 2000}{\text{The square of the velocity of the circumference in feet per second.}} \text{ equals weight in cwts.}$$

Relative Value of Heating Surface.

Horizontal surfaces above the flame equal	1.00
Vertical surfaces above the flame equal	.50
Horizontal surfaces beneath the flame	.10

Tubes and flues equal 1¼ times their diameter.
Convex surfaces above the flame equal 1 1-6 diam.

Feed Water Required by Small Boilers.

Gauge Pressure at Boiler.	Lbs. Water per Effective H. P. per Hour.	Gauge Pressure at Boiler.	Lbs. Water per Effective H. P. per Hour.
10	118	60	75
15	111	70	71
20	105	80	68
25	100	90	65
30	93	100	63
40	84	120	61
50	79	150	58

How to Clean a Water Gauge Glass on a Steam Boiler Without Removing Same.

1. Draw a cupful of hot water from the boiler, into which pour at least a tablespoonful of raw muriatic or other acid.

2. Close both water gauge valves.

3. Open top water gauge valve and also pet cock at bottom and blow water out of the glass. Then immediately close the top valve and submerge the end of the pet cock in cup of hot water solution. A vacuum is at once created in the gauge glass which causes the solution in the cup to rush in.

4. Keep the pet cock immersed and operate the top valve, slightly opening and closing, alternately expelling and drawing in the solution until all grease, oil, or other matter adhering to the inside of the glass is cut out. Then close pet cock and open both water gauge valves.

It is necessary to have one pound pressure of steam or more on the boiler before commencing this operation, which need not occupy more than ten minutes. The result is a clean glass without the risk of breakage and probable renewal of gaskets, which is frequently the case when removing the glass for cleaning.

Removing Oil and Grit from Steam Boiler.

Unavoidable accumulation of oil, grease or grit in a new system causes a boiler to foam, prevents generation of steam, and produces an unsteady water line; therefore it is necessary to blow off boiler under pressure.

1. Close off the main steam and return valves, or all radiator valves.
2. Make a wood fire and get up a pressure of at least ten pounds as indicated by the steam gauge.
3. Open the blow-off valves, being careful that just sufficient fire is carried to maintain a pressure until the last gallon of water is exhausted.
4. Allow fire to die out.
5. Open all fire and flue doors and in about half an hour.
6. Close blow-off valve and
7. Refill boiler slowly to water line.
8. Open all radiator and main valves and
9. Start fire.

A boiler should be blown off within a week after it is installed and in operation. If one blowing off does not result in clean water gauge glass, proper generation of steam and a steady water line, the boiler should be blown off a second, and if necessary a third and fourth time.

NAMES AND SIZES OF COAL.

Anthracite or "Hard."

The ordinary sizes and designations of "Domestic" hard coals are:

Names of Sizes	Will pass through	Will not pass through
"Pea"	¾ inch mesh	½ inch mesh
"Chestnut," or "Nut"	1¼ inch mesh	¾ inch mesh
"Stove," or "Range"	1¾ inch mesh	1¼ inch mesh
"Egg"—In the East	2½ inch mesh	1¾ inch mesh
"Large Egg"—Chicago	4 inch mesh	2¾ inch mesh
"Small Egg"—Chicago	2¾ inch mesh	2 inch mesh
"Broken," or "Grate"	4 inch mesh	2½ inch mesh

Bituminous or "Soft."

For "Domestic" soft coals there are no uniform names and sizes; but they are marketed in the various states under about these classes; "Screenings" usually smallest sizes.

"Duff" goes through ⅛ in. screen.

"No. 3 Nut" goes through 1¼ in. screen, over ¾ in. screen.

"No. 2 Nut" goes through 2 in. screen, over 1¼ in. screen.

"No. 1 Domestic Nut" goes through 3 in. screen, over 1½ or 2 in. screen.

"No. 4 Washed" goes through ¾ in. screen, over ¼ in. screen.

"No. 3 Washed Chestnut" goes through 1¼ in. screen, over ¾ in. screen.

"No. 2 Washed Stove" goes through 2 in. screen, over 1¼ in. screen.

"No. 1 Washed Egg" goes through 3 in. screen, over 2 in. screen.

"No. 3 Roller Screened Nut" goes through 1½ in. screen, over 1 in. screen.

"No. 2 Roller Screened Nut" goes through 2 in. screen, over 1½ in. screen.

"No. 1 Roller Screened Nut" goes through 3½ in. screen, over 2 in. screen.

"Egg" goes through 6 in. screen, over 3 in. screen.

"Lump" or "Block" goes through 6 in. screen, or over.

"Run-of-Mine" in fine and large lumps.

POCAHONTAS SMOKELESS: Generally sized as: "Nut," "Egg," "Lump," and "Mine-Run."

CANNEL COAL: For fireplaces:—"Hand Picked Lump"; for stoves:—"Egg."

DOMESTIC BY-PRODUCT COKE: "Egg," 3 in.-2½ in.
"Large Stove," 2½ in.-2 in. "Small Stove," 2 in.-1½ in.
"Nut," 1½ in.-¾-in. "Pea," ¾ in.-½ in.

Combustion of Coal and Oil.

Volume of Chemically Required Air Given in the Two Columns at Right	Weight of Air Required, Lbs.	
	For Coal	For Oil
CARBON		
Coal, 11.6 lb. air × 0.8226 lb. C	9.54	....
Oil, 11.6 lb. air × 0.8764 lb. C	....	10.06
HYDROGEN		
Coal, 34.8 lb. air × 0.0389 lb. H	1.35	....
Oil, 34.8 lb. air × 0.104 lb. H	....	3.62
SULPHUR		
Coal, 4.3 lb. air × 0.0049 lb. S	0.02	0.04
Oil, 4.3 lb. air × 0.010 lb. S	....	....
Lbs. of air required	10.91	13.82
Weight of the combustibles (after deducting ash from coal)	0.91	1.00
Total weight which will be considered as dry chimney gas	11.82	14.82

—Proceedings of American Society of Mechanical Engineers.

HEAT OF COMBUSTION OF FUELS

FUEL	Air chemically consumed per pound of fuel		Total heat of combustion of one pound of fuel	Equivalent evaporative poweer from and at 212° F., water per pound of fuel
	Lbs.	Cu. ft. at 62° F.	Units	Lbs.
Coal of average composition.	10.7	140	14,700	15.22
Coke	10.81	142	13,548	14.02
Lignite	8.85	116	13,108	13.57
Asphalt	11.85	156	17,040	17.64
Wood desiccated	6.09	80	10,974	11.36
Wood, 25% moisture	4.57	60	7,951	8.20
Wood, charcoal, desiccated	9.51	125	13,006	13.46
Peat, desiccated	7.52	99	12,279	12.71
Peat, 30% moisture	5.24	69	8,260	9.53
Peat, charcoal, desiccated	9.9	130	12,325	12.76
Straw	4.26	56	8,144	8.43
Petroleum	10.33	188	20,411	21.13
Petroleum oils	17.33	235	27,531	28.50
Coal gas per cu. ft. at 62° F.			630	.70

RELATIVE VALUE OF VARIOUS WOODS

WOOD	Specific Gravity	One Cubic Foot	Pounds in one Cord	Relative value of Wood	Val. with Hickory at $5.00 per Cord
Hickory Shell bark	1.000	62	4.469	1.00	$5.00
White Oak	0.885	53	3.821	0.81	4.05
White Ash	0.772	49	3.450	0.77	3.85
Red Oak	0.728	45½	3.254	0.69	4.45
White Beech	0.724	45	3,236	0.65	3.25
Black Walnut	0.681	42½	3,044	0.65	3.25
Red Cedar	0.665	35	2,525	0.56	2.08
Hard Maple	0.644	40	2,878	0.60	3.00
Soft Maple	0.597	37	2,668	0.54	2.70
Yellow Pine	0.550	34	2.463	0.54	2.70
Butternut	0.567	35½	2,534	0.51	2.55
White Pine	0.418	26	1,866	0.42	2.10
Chestnut	0.552	32	2,333	0.52	2.60

Locating Radiators.

Direct Radiation.

Direct radiation should be set along the exposed or cold walls or under the windows, in order to warm the cold currents of air produced by these exposures.

If placed on the warm side of a room the tendency is to cause a draft of cold air across the floor, endangering health, or, if nothing worse, causes cold feet. Usually, in residences, sufficient radiation is placed on the first (or lower) hall to heat the cubic contents of the halls on all floors, but in a three-story building, where the halls are large, we advise the placing of some radiation in the second floor, unless there is an unprotected glass exposure (sky-light) over the hall, in which case the radiation should be put in the third story instead of second, to heat the cold air as it descends.

Weight and Measurement of a Square Foot of Radiation.

A foot of prime radiation should weigh 6¾ pounds and hold one pint of water.

Radiation of Different Sizes of Wrought Iron Pipe.

Following table gives the actual lengths of different size pipe sufficient to make ten square feet of radiation.

1 -inch pipe, 28 lineal feet=10 square feet radiation.
1¼-inch pipe, 24 lineal feet=10 square feet radiation.
1½-inch pipe, 20 lineal feet=10 square feet radiation.
2 -inch pipe, 16 lineal feet=10 square feet radiation.
2½-inch pipe, 13 lineal feet=10 square feet radiation.
3 -inch pipe, 11 lineal feet=10 square feet radiation.

Ordinary atmosphere will sustain 33.9 ft. of water in height.

35.84 cu. ft of water=1 ton.

39.84 cu. ft. of ice=1 ton.

1 cu. ft. of sea water=64.3 ℔.

Sea water contains 4 to 5 oz. of salt per gallon.

Weights of Different Metals.

Lead	1 foot square, inch thick=59.06
Copper	1 foot square, inch thick=45.3
Wrought-iron	1 foot square, inch thick=40.5
Cast-iron	1 foot square, inch thick=37.54
Cast-steel	1 foot square, inch thick=40.83

Under no consideration should lead be used in fittings as lead has a tendency to stop the circulation in time. A good practical man will always lead on the threads.

Pipe and Fittings.

Use ample-sized pipe. If one or two sizes large it will not be detrimental to the successful circulation of the steam or water, but if too small will in all probability cause failure. Pipes of ample size are the most satisfactory and economical in the long run. Use fittings which will allow of the free and rapid circulation of the steam or water, connecting them in such a manner as to permit proper expansion and contraction of the pipe.

Shrinkage of Castings.

Pattern-makers'	rule	for	Cast-Iron ..1/8		of an inch longer per linear foot.
"	"	"	"	Brass 3/16	
"	"	"	"	Lead 1/8	
"	"	"	"	Tin 1/12	
"	"	"	"	Zinc 3/16	

Weight of One Cubic Foot of Pure Water.

At 32 degrees Fahr. (freezing point)	62.418 lbs.
At 39.1 degrees Fahr. (maximum density)	62.425 lbs.
At 62 degrees Fahr. (standard temperature)	62.355 lbs.
At 212 degrees Fahr. (boiling point, under 1 atmosphere)	59.76 lbs.
Imperial gallon=277,274 cubic inches of water at 62 degrees Fahr.	10 lbs.
American gallon=231 cubic inches of water at 62 degrees Fahr.	8.3356 lbs.

WEIGHTS AND MEASURES

Cubic Measure.

1728 cubic inches	equal	1 cubic foot, cu. ft.
27 cubic feet	“	1 cubic yard, cu. yd.
128 cubic feet	“	1 cord, cd.
24¾ cubic feet	“	1 perch, P.

1 cu. yd. equals 27 cu. ft. equals 46,656 cu. in.

Measure of Angles or Arcs.

60 seconds (″)	equal	1 minute, ′.
60 minutes	“	1 degree, °.
90 degrees	“	1 rt. angle or quadrant.
360 degrees	“	1 circle, cir.

1 cir. equals 360° equals 21,600′ equals 1,296,000″.

Avoirdupois Weight.

437.5 grains	equal	1 ounce, oz.
16 ounces	“	1 pound, lb.
100 pounds	“	1 hundredweight, cwt.
20 hundredweight	“	1 ton, T.

1 T. equals 20 cwt. equals 2000 lb. equals 32,000 oz. equals 14,000,000 gr.

The avoirdupois pound contains 7000 grains.

Long Ton Weight.

16 ounces	equal	1 pound, lb.
112 pounds	“	1 hundredweight, cwt.
20 cwt. or 2240 lbs	“	1 ton, T.

Troy Weight.

24 grains	equal	1 pennyweight, pwt.
20 pennyweight	“	1 ounce, oz.
12 ounces	“	1 pound, lb.

1 lb. equals 12 oz. equals 240 pwt. equals 5760 gr.

Apothecary's Weight.

20 grains	equal	1 scruple, sc.
3 scruples	“	1 dram, dr.
8 drams	“	1 ounce, oz.
12 ounces	“	1 pound, lb.

1 lb. equals 12 oz. equals 96 dr. equals 288 sc. equals 5760 gr.

WEIGHTS AND MEASURES

Liquid Measure.

4 gills	equal	1 pint, pt.
2 pints	"	1 quart, qt.
4 quarts	"	1 gallon, gal.
31½ gallons	"	1 barrel, bbl.
2 barrels or 63 gal.	"	1 hogshead, hhd.

1 hhd. equals 2 bbl. equals 63 gal. equals 252 qt. equals 504 pt. equals 2016 gi.

The U. S. gallon contains 231 cu. in. equals .134 cu. ft. nearly.

With water at its maximum density (weighing 62.425 lb. per cu. ft.) a gallon of pure water weighs 8.345 lb.

Dry Measure.

2 pints	equal	1 quart, qt.
8 quarts	"	1 peck, pk.
4 pecks	"	1 bushel, bu.

1 bu. equals 4 pk. equals 32 qt. equals 64 pt.

The U. S. struck bushel contains 2,150.42 cu. in. equal 1.2444 cu. ft. Its dimensions are, by law, 18½ in. in diameter and 8 in. deep. The dry gallon contains 268.8 cu. in., being ⅛ bu.

Approximately the bushel may be taken at 1¼ cu. ft.

Miscellaneous Table.

12 article—1 dozen.
12 dozen—1 gross.
12 gross—1 great gross.
2 articles—1 pair.
20 articles—1 score.
24 sheets—1 quire.

20 quires—1 ream.
1 league—3 miles.
1 fathom—6 feet.
1 hand—4 inches.
1 palm—3 inches.
1 span—9 inches.

1 knot (U. S.) equals 6,086.07 ft. equals 1⅙ miles nearly. 1 meter equals 3 feet 3⅜ inches nearly.

Boiling Points of Various Fluids.

Water in Vacuum	98°
Water, Atmospheric Pressure	212°
Alcohol	173°
Sulphuric Acid	240°
Refined Petroleum	316°
Turpentine	315°
Sulphur	570°
Linseed Oil	597°

Melting Points of Different Metals.

Aluminum	1400°
Antimony	1150°
Bismuth	507°
Brass	1900°
Bronze	1692°
Copper	1996°
Glass	2377°
Gold (pure)	2066°
Iron (cast)	2786°
Iron (wrought)	2912°
Lead	617°
Platinum	3080°
Silver (pure)	1873°
Steel	2500°
Tin	446°
Zinc	773°

Weights and Measures.

Measure of Length.

4 inches make 1 hand.
7.92 inches make 1 link.
18 inches make 1 cubit.
12 inches make 1 foot.
6 feet make 1 fathom.
3 feet make 1 yard.
5½ yards make 1 rod or pole.

Measure of Length—Continued.

40 poles make 1 furlong.
8 furlongs make 1 mile.
$69\frac{1}{6}$ miles make 1 degree.
60 geographical miles make 1 degree.

1760 yards 5280 feet	1 mile.

Measure of Surface.

144 square inches make 1 square foot.
9 square feet make 1 square yard.
30¼ square yards make 1 rod, perch or pole.
40 square rods make 1 square rood.
4 square roods make 1 square acre.
10 square chains make 1 square acre.
640 square acres make 1 square mile.
Gunter's chain equal to 22 yards or 100 links.
272¼ square feet make 1 square rod.
43,560 square feet make 1 acre.

Measure of Solidity.

1728 cubic inches make 1 cubic foot.
27 cubic feet make 1 cubic yard.

Firing.

Steam.

Experience teaches us that in many cases where the water leaves the boiler and goes into the radiation the trouble is caused by improper firing.

The steam gets low either from neglect or over night, and the fireman, desiring to get the steam up as soon as possible, opens the ash-pit door, and with a strong draft in chimney flue urges up the fire to an intensity far beyond what the boiler needs, and this causes the water to boil so furiously that it lifts out of the boiler. The ash-pit door is only made to gain access to the pit to take out the ashes, and should be used for this purpose only, and not to create draft, as the draft door is made sufficiently large to admit all the air necessary for combustion. In other words, don't put a 12-horse power fire under a 4-horse power boiler.

Caution.

If the water should disappear from the gauge glass, do not draw the fire, but cover it with wet ashes, and allow the boiler to cool before refilling with water.

When connecting damper regulator adjust the chains so that both the draft door and check draft door will be **closed** when the regulator lever is level, and there is no steam in the boiler. In this position chain should be tight.

Metal That Expands in Cooling.

Lead, 75; antimony, 16.7; and bismuth, 18.3.

Expansion of solids from 32° to 212°, at 32° being equal to 1.

Brass	1.00191
Common brick	1.00055
Cast iron	1.00111
Cement	1.00144
Copper	1.00175
Fire brick	1.0175
Glass	1.00085
Granite	1.00079

Water expands .1 of its bulk in freezing.

A column of water 2.3 ft. high equals 1 ℔. per sq. in. pressure.

EIGHT HOUR DAY WAGES TABLE—*48* Hours Per Week

$5 83	$5½ 92	$6 100	$6½ 108	$7 117	$7½ 125	$8 133	Per Week Per Day. Hours.	Days	$½ 08	$9 150	$10 167	$10½ 175	$11 183	$12 200	$13 217	$13½ 225	$14 233
05	06	07	07	07	08	08	½		01	09	10	11	11	13	14	14	15
10	11	13	14	15	16	17	*1*		01	19	21	22	23	25	27	28	29
21	23	25	27	29	31	33	*2*	¼	02	38	42	44	46	50	54	56	58
31	34	38	41	44	47	50	*3*		03	56	63	66	69	75	81	84	88
42	46	50	54	58	63	67	*4*	½	04	75	83	88	92	100	108	113	117
52	57	63	68	73	78	83	*5*		05	94	104	109	115	125	135	141	146
63	69	75	81	88	94	100	*6*	¾	06	113	125	131	138	115	0163	169	175
73	80	88	95	102	109	117	*7*		07	131	146	153	160	175	190	197	204
83	92	100	108	117	125	133	*8*	1	08	150	167	175	183	200	217	225	233
94	103	113	122	131	141	150	*9*		09	169	188	197	206	225	244	253	263
104	115	125	135	146	156	167	*10*	1¼	10	188	208	219	229	250	271	281	292
125	138	150	163	175	188	200	*12*	1½	13	225	250	263	275	300	325	338	350
167	183	200	217	233	250	267	*16*	2	17	330	333	350	367	400	433	450	467
208	229	250	271	292	313	333	*20*	2½	21	375	417	438	458	500	542	563	583
250	275	300	325	350	375	400	*24*	3	25	450	500	525	550	600	650	675	700
292	321	350	379	408	438	467	*28*	3½	29	525	583	613	642	700	758	788	817
313	344	375	406	438	469	500	*30*	3¾	31	563	625	656	688	750	813	844	875
333	367	400	433	467	500	533	*32*	4	33	600	667	700	733	800	867	900	933
354	390	425	460	496	531	567	*34*	4¼	35	638	708	744	779	850	921	956	922
375	413	450	488	525	563	600	*36*	4½	38	675	750	788	825	900	975	1013	1050
396	435	475	515	554	594	633	*38*	4¾	40	713	792	831	871	950	1029	1069	1108
406	447	488	528	569	609	650	*39*		41	731	813	853	894	975	1056	1097	1138
417	458	500	542	583	625	667	*40*	5	42	750	833	875	917	1000	1083	1125	1167
427	470	513	555	598	641	683	*41*		43	769	854	897	940	1025	1110	1153	1196
438	481	525	569	613	656	700	*42*	5¼	44	788	875	919	963	1050	1138	1181	1225
448	493	538	582	627	672	717	*43*		45	806	896	940	985	1075	1165	1209	1254
458	504	550	596	642	688	733	*44*	5½	46	825	917	963	1008	1100	1192	1238	1283
469	516	563	609	656	703	750	*45*		47	844	938	984	1031	1125	1219	1266	1313
479	527	575	623	671	719	767	*46*	5¾	48	863	958	1006	1054	1150	1246	1294	1342
490	539	588	636	685	734	783	*47*		49	881	979	1028	1077	1175	1273	1322	1371
500	550	600	650	700	750	800	*48*	6	50	900	$10	1050	1100	1200	1300	1350	1400

$15 250	$16 267	$16½ 275	$17 283	$18 300	$19½ 325	Per Week Per Day Hours.	Days.	$20 333	$21 350	$22 367	$22½ 375	$24 400	$25 417	$27 450	$30 500
16	17	17	18	19	20	½		21	22	23	23	25	26	28	31
31	33	34	35	38	41	*1*		42	44	46	47	50	52	56	63
63	67	69	71	75	81	*2*	¼	83	88	92	94	100	104	113	125
94	100	103	106	113	122	*3*		125	131	138	141	150	156	169	188
125	133	138	142	150	163	*4*	½	167	175	183	188	200	208	225	250
156	167	172	177	188	203	*5*		208	219	229	234	250	260	281	313
188	200	206	213	225	244	*6*	¾	250	263	275	281	300	313	338	375
219	233	241	248	263	284	*7*		292	306	321	328	350	365	394	438
250	267	275	283	300	325	*8*	1	333	350	367	375	400	417	450	500
281	300	309	319	338	366	*9*		375	394	413	422	450	469	506	563
313	333	344	354	375	406	*10*	1¼	417	438	458	469	500	521	563	625
375	400	413	425	550	488	*12*	1½	500	525	550	563	600	625	675	750
500	533	550	567	600	650	*16*	2	667	700	733	750	800	833	900	1000
625	667	688	708	750	813	*20*	2½	833	875	917	938	1000	1042	1125	1250
750	800	825	850	900	975	*24*	3	1000	1050	1100	1125	1200	1250	1350	1500
875	933	963	992	1050	1138	*28*	3½	1167	1225	1283	1313	1400	1458	1575	1750
938	1000	1031	1063	1125	1219	*30*	3¾	1250	1313	1375	1406	1500	1563	1688	1875
1000	1067	1100	1133	1200	1300	*32*	4	1333	1400	1467	1500	1600	1667	1800	2000
1063	1133	1169	1204	1275	1381	*34*	4¼	1417	1488	1558	1594	1700	1771	1913	2125
1125	1200	1238	1275	1350	1463	*36*	4½	1500	1575	1650	1688	1800	1875	2025	2250
1188	1267	1306	1346	1425	1544	*38*	4¾	1583	1663	1742	1781	1900	1979	2138	2375
1219	1300	1341	1381	1463	1584	*39*		1625	1706	1788	1828	1950	2031	2194	2438
1250	1333	1375	1417	1500	1625	*40*	5	1667	1750	1833	1875	2000	2083	2250	2500
1281	1367	1409	1452	1538	1666	*41*		1708	1794	1879	1922	2050	2135	2306	2563
1313	1400	1444	1488	1575	1706	*42*	5¼	1750	1838	1925	1969	2100	2188	2363	2625
1344	1433	1478	1523	1616	1747	*43*		1792	1881	1971	2016	2150	2240	2419	2688
1375	1467	1513	1558	1650	1788	*44*	5½	1833	1925	2017	2063	2200	2292	2475	2750
1406	1500	1547	1594	1688	1828	*45*		1875	1969	2063	2109	2250	2344	2531	2813
1438	1533	1581	1629	1725	1869	*46*	5¾	1917	2013	2108	2156	2300	2396	2588	2875
1469	1567	1616	1665	1763	1909	*47*		1958	2056	2154	2203	2350	2448	2644	2938
1500	1600	1650	1700	1800	1950	*48*	6	2000	2100	2200	2250	2400	2500	2700	3000

At $9 per Week ($1.50 per Day), the Wages for 46 Hours (5¾ Days) amount to $8.63.

TABLE showing EQUIVALENT of several Discounts; Proceeds on $; Profit on Cost.

A	B	C	D	E	A	B	C	D	E
	And		Cents on the Dollar.	Per Cent Profit (see last col.)		And		Cents on the Dollar.	
1 %	0%off	= 1%off	99	1 01	**60** %	0%off	=60%off	40	150
2 “	0 “	= 2 “	98	2 04	60 “	2½“	=61 “	39	156 41
3 “	0 “	= 3 “	97	3 09	60 “	5 “	=62 “	38	163 16
4 “	0 “	= 4 “	96	4 17	60 “	7½“	=63 “	37	170 27
5 “	0 “	= 5 “	95	5 26	60 “	10 “	=64 “	36	177 78
6 “	0 “	= 6 “	94	6 38	60 “	12½“	=65 “	35	185 71
7 “	0 “	= 7 “	93	7 53	60 “	15 “	=66 “	34	194 12
8 “	0 “	= 8 “	92	8 70	60 “	17½“	=67 “	33	203 03
10 “	**0** “	=10 “	90	11 11	60 “	20 “	=68 “	32	212 50
10 “	2½“	=12¼“	87¾	13 96	60 “	22½“	=69 “	31	222 58
10 “	5 “	=14½“	85½	16 96	**60** “	25 “	=70 “	30	233 33
12½“	**0** “	=12½“	87½	14 29	60 “	27½“	=71 “	29	244 83
12½“	2½“	=14⅔“	85⅓	*17 19	60 “	30 “	=72 “	28	257 14
12½“	5 “	=16⅞“	83⅛	20 30“	60 “	33⅓“	=73⅓“	26	275
15 “	**0** “	=15 “	85	17 65“	60 “	35 “	=74 “	26⅔	284 62
15 “	2½“	=17⅛“	82⅞	20 66“	60 “	37½“	=75 “	25	300
15 “	5 “	=19¼“	80¾	23 84“	66 “	40 “	=76 “	24	316 67
15 “	10 “	=23½“	76½	30 72“	60 “	42½“	=77 “	23	334 78
16⅔“	**0** “	=16⅔“	83⅓	20 “	60 “	45 “	=78 “	22	354 55
16⅔“	2½“	=18¾“	81¼	23 08“	60 “	47½“	=79 “	21	376 19
16⅔“	5 “	=20⅚“	79⅙	26 32“	60 “	50 “	=80 “	20	400
16⅔“	10 “	=25 “	75	33 33“	**66⅔**“	**0** “	=66⅔“	33⅔	200
20 “	**0** “	=20 “	80	25 “	66⅔“	5 “	=68⅓“	31⅓	215 79
20 “	2½“	=22 “	78	28 21“	66⅔“	10 “	=70 “	30	233 33
20 “	5 “	=24 “	76	31 58“	66⅔“	20 “	=73⅓“	26⅔	275
20 “	10 “	=28 “	72	38 89“	66⅔“	25 “	=75 “	25	300
20 “	15 “	=32 “	68	47 06“	66⅔“	33⅓“	=$77\frac{7}{9}$“	$22\frac{2}{9}$	350
25 “	**0** “	=25 “	75	33 33“	66⅔“	40 “	=80 “	20	400
25 “	2½“	=26⅞“	73⅛	36 75“	66⅔“	50 “	=83⅓“	16⅔	500
25 “	5 “	=28¾“	71¼	40 35“	**70** “	**0** “	=70 “	30	233 33
25 “	10 “	=32½“	67½	48 15“	70 “	5 “	=71½“	28½	250 88
25 “	20 “	=40 “	60	66 67“	70 “	10 “	=73 “	27	270 37
30 “	**0** “	=30 “	70	42 86“	70 “	20 “	=76 “	24	316 67
30 “	2½“	=31¾“	68¼	46 52“	70 “	25 “	=77½“	22½	344 44
30 “	5 “	=33½“	66½	50 38“	70 “	30 “	=79 “	21	376 19
30 “	10 “	=37 “	63	58 73“	70 “	33⅓“	=80 “	20	400
30 “	20 “	=44 “	56	78 57“	70 “	40 “	=82 “	18	455 56
33⅓“	**0** “	=33⅓“	66⅔	50 “	70 “	50 “	=85 “	15	566 67
33⅓“	2½“	=35 “	65	53 85“	**75** “	**0** “	=75 “	25	300
33⅓“	5 “	=36⅔“	63⅓	57 89“	75 “	5 “	=76¼“	23¾	321 05
33⅓“	10 “	=40 “	60	66 67“	75 “	10 “	=77½“	22½	344 44
33⅓“	20 “	=46⅔“	53⅓	87 50“	75 “	20 “	=80 “	20	400
33⅓“	25 “	=50 “	50	100 “	75 “	25 “	=81¼“	18¾	433 33
35 “	0 “	=35 “	65	53 85“	75 “	30 “	=82½“	17½	471 43
37½“	0 “	=37½“	62½	60 “	75 “	33⅓“	=83⅓“	16⅔	500
40 “	**0** “	=40 “	60	66 67“	75 “	40 “	=85 “	15	566 67
40 “	2½“	=41½“	58½	70 94“	75 “	50 “	=87½“	12½	700
40 “	5 “	=43 “	57	75 44“	**80** “	**0** “	=80 “	20	400
40 “	10 “	=46 “	54	85 19“	80 “	5 “	=81 “	19	426 32
40 “	15 “	=49 “	51	96 08“	80 “	10 “	=82 “	18	455 56
40 “	20 “	=52 “	48	108 33“	80 “	20 “	=84 “	16	525
40 “	25 “	=55 “	45	122 22“	80 “	25 “	=85 “	15	566 67
40 “	30 “	=58 “	42	138 10“	80 “	30 “	=86 “	14	614 29
40 “	33⅓“	=60 “	40	150 “	80 “	40 “	=88 “	12	733 33
45 “	0 “	=45 “	55	81 82“	80 “	50 “	=90 “	10	900
40 “	**0** “	=50 “	50	100 “	80 “	60 “	=92 “	08	1150
50 “	2½“	=51¼“	48¾	105 13“	**90**	**0** “	=90 “	10	900
50 “	5 “	=52½“	47½	110 53“	90 “	10 “	=91 “	09	1011 11
50 “	10 “	=55 “	45	122 22“	90 “	20 “	=92 “	08	1150
50 “	15 “	=57½“	42½	135 29“	90 “	30 “	=93 “	07	1328 57
50 “	20 “	=60 “	40	150 “	90 “	40 “	=94 “	06	1566 67
50 “	25 “	=62½“	37½	166 67“	90 “	50 “	=95 “	05	1900
50 “	30 “	=65 “	35	185 71“	90 “	60 “	=96 “	04	2400
50 “	33⅓“	=66⅔“	33⅓	200 “	90 “	70 “	=97 “	03	3233 33
50 “	40 “	=70 “	30	233 33“	90 “	80 “	=98 “	02	4900
55 “	0 “	=55 “	45	122 22“	90 “	90 “	=99 “	01	9900

The **whole** Discount is shown in Col. C, when **two** (A and B) are given. Thus 40.% off (A) and 10 off remainder (B),= 46% off (C); which = 54c on the $ (D,)&c (See Art. 194). The Rules an Principles of Trade Discount are clearly set forth in Arts. 190 to 199.

TABLE Aiding DEALERS, MANUFACTURERS—Fixing Prices, Profits, Discounts.

For Retail Trade			For Wholesale Trade			Manufacturers, Jobbers		
If you Add to Cost Price	And deduct off Retail Price	Profit on Cost will be	If you Buy (of List) at	And Sell (same List) at	Profit on Cost will be	In order to give Trade	And realize on Cost	List Price must be
10 %	2½%	7¼%	10%off	2½%off	8⅓ %	10%off	10 %	1 2/9 Times the Cost.
10 “	5 “	4½“	10 “	5 “	5 5/9“	10 “	20 “	1⅓
12½“	5 “	6⅞“	12½“	5 “	8 4/7“	12½“	20 “	*1⅜
15 “	5 “	9¼“	15 “	5 “	*11¾“	15 “	20 “	*1⅝
16⅔“	5 “	10⅚“	16⅔“	5 “	14¾“	16⅔“	20 “	*1 4/9
20 “	2½“	17 “	20 “	5 “	18¾“	20 “	20 “	1½
20 “	5 “	14 “	20 “	10 “	12½“	20 “	30 “	1⅝
20 “	10 “	8 “	20 “	12½ “	9⅜“	20 “	40 “	1¾
20 “	12½“	5 “	20 “	15 “	6¼“	20 “	50 “	1⅞
25 “	2½“	21⅞	25 “	5 “	26⅔“	25 “	20 “	1⅗“
25 “	5 “	18¾“	25 “	10 “	20 “	25 “	30 “	*1¾“
25 “	10 “	12½“	25 “	15 “	13⅓“	25 “	40 “	*1⅞“
25 “	15 “	6¼“	25 “	20 “	6⅔“	25 “	50 “	2 “
30 “	2½“	26¾“	30 “	10 “	28 4/7“	30 “	20 “	1 5/7“
30 “	5 “	23½“	30 “	15 “	21 3/7“	30 “	30 “	1 6/7“
30 “	10 “	17 “	30 “	20 “	14 2/7“	30 “	40 “	2 “
30 “	15 “	10½“	30 “	25 “	7⅐“	30 “	50 “	2⅐“
33⅓“	2½“	30 “	33⅓“	10 “	35 “	33⅓“	20 “	1⅘“
33⅓“	5 “	26⅔“	33⅓“	15 “	27½“	33⅓“	33⅓“	2 “
33⅓“	10 “	20 “	33⅓“	20 “	20 “	33⅓“	40 “	2⅒“
33⅓“	15 “	13⅓“	33⅓“	25 “	12½“	33⅓“	50 “	2¼“
33⅓“	20 “	6⅔“	33⅓“	30 “	5 “	33⅓“	60 “	2⅖“
40 “	2½“	36½“	40 “	10 “	50 “	40 “	20 “	2 “
40 “	5 “	33 “	40 “	15 “	41⅔“	40 “	30 “	2⅙“
40 “	10 “	26 “	40 “	20 “	33⅓“	40 “	40 “	2⅓“
40 “	15 “	19 “	40 “	25 “	25 “	40 “	50 “	2½“
40 “	20 “	12 “	40 “	30 “	16⅔“	40 “	60 “	2⅔“
40 “	25 “	5 “	40 “	33⅓ “	11⅑“	40 “	80 “	3 “
50 “	5 “	42½“	50 “	10 “	80 “	50 “	33⅓“	2 8/3“
50 “	10 “	35 “	50 “	20 “	60 “	50 “	40 “	2⅘“
50 “	15 “	27½“	50 “	25 “	50 “	50 “	50 “	3 “
50 “	20 “	20 “	50 “	30 “	40 “	50 “	60 “	3⅕“
50 “	25 “	12½“	50 “	33⅓ “	33⅓“	50 “	80 “	3⅗“
50 “	30 “	5 “	50 “	40 “	20 “	50 “	100 “	4 “
60 “	5 “	52 “	60 “	20 “	100 “	60 “	33⅓“	3⅓“
60 “	10 “	44 “	60 “	25 “	87½“	60 “	40 “	3½“
60 “	15 “	36 “	60 “	30 “	75 “	60 “	50 “	3¾“
60 “	20 “	28 “	60 “	33⅓ “	66⅔“	60 “	60 “	4 “
60 “	25 “	20 “	60 “	40 “	50 “	60 “	70 “	4¼“
60 “	30 “	12 “	60 “	45 “	37½“	60 “	80 “	4½“
60 “	33⅓“	6⅔“	60 “	50 “	25 “	60 “	100 “	5 “
66⅔“	10 “	50 “	66⅔“	20 “	140 “	66⅔“	33⅓“	4 “
66⅔“	15 “	41⅔“	66⅔“	25 “	125 “	66⅔“	40 “	4⅕“
66⅔“	20 “	33⅓“	66⅔“	33⅓ “	100 “	66⅔“	50 “	4½“
66⅔“	25 “	25 “	66⅔“	40 “	80 “	66⅔“	60 “	4⅘“
66⅔“	30 “	16⅔“	66⅔“	50 “	50 “	66⅔“	80 “	5⅖“
66⅔“	33⅓“	11⅑“	66⅔“	60 “	20 “	66⅔“	100 “	6 “
70 “	10 “	53 “	70 “	25 “	150 “	70 “	33⅓“	4 4/9“
70 “	15 “	44½“	70 “	30 “	133⅓“	70 “	40 “	4⅔“
70 “	20 “	36 “	70 “	33⅓ “	122 2/9“	70 “	50 “	5 “
70 “	25 “	27½“	70 “	40 “	100 “	70 “	60 “	5⅓“
70 “	30 “	19 “	70 “	50 “	66⅔“	70 “	80 “	6 “
70 “	33⅓“	13⅓“	70 “	60 “	33⅓“	70 “	100 “	6⅔“
75 “	10 “	57½“	75 “	30 “	180 “	75 “	33⅓“	5⅓“
75 “	15 “	48¾“	75 “	40 “	140 “	75 “	40 “	5⅗“
75 “	20 “	40 “	75 “	50 “	100 “	75 “	50 “	6 “
75 “	25 “	31¼“	75 “	60 “	60 “	75 “	60 “	6⅖“
75 “	30 “	22½“	75 “	66⅔ “	33⅓“	75 “	80 “	7⅕“
75 “	33⅓“	16⅔“	75 “	70 “	20 “	75 “	100 “	8 “
80 “	10 “	62 “	80 “	30 “	250 “	80 “	33⅓“	6⅔“
80 “	15 “	53 “	80 “	40 “	200 “	80 “	40 “	7 “
80 “	20 “	44 “	80 “	50 “	150 “	80 “	50 “	7½“
80 “	25 “	35 “	80 “	60 “	100 “	80 “	60 “	8 “
80 “	30 “	26 “	80 “	70 “	50 “	80 “	80 “	9 “
80 “	33⅓“	20 “	80 “	75 “	25 “	80 “	100 “	10 “

(A). If you mark goods to make 40% profit (col.1), then sell at a discount of 20% from marking price (c.2), your profit will be 12% on cost (c.3). (Art. 195).

(B). If you buy at 50% off (col. 1), and sell to the Trade or Agents at 40% off same List (col.2), your profit will be 20% on cost (col.3) (See Rule, Art. 196).

(C.) In order to give the Trade or Agents 50% off (col. 1), and still make 100% profit on the cost (c.2), the List price must be 4 times the cost (c.3). (Art. 197).

These Tables will save Buyers and Sellers many abstruse Calculations.

PERPETUAL CALENDAR

GOOD FOR THREE CENTURIES

1800	1801	1802	1803	.....	**1804**	1805
1806	1807	.....	**1808**	1809	1810	1811
.....	**1812**	1813	1814	1815	.....	**1816**
1817	1818	1819	.....	**1820**	1821	1822
1823	.....	**1824**	1825	1826	1827	.....
1828	1829	1830	1831	.....	**1832**	1833
1834	1835	.....	**1836**	1837	1838	1839
.....	**1840**	1841	1842	1843	.....	**1844**
1845	1846	1847	.....	**1848**	1849	1850
1851	.....	**1852**	1853	1854	1855	.....
1856	1857	1858	1859	.....	**1860**	1861
1862	1863	.....	**1864**	1865	1866	1867
.....	**1868**	1869	1870	1871	.....	**1872**
1873	1874	1875	.....	**1876**	1877	1878
1879	.....	**1880**	1881	1882	1883	.....
1884	1885	1886	1887	.....	**1888**	1889
1890	1891	.....	**1892**	1893	1894	1895
.....	**1896**	1897	1898	1899	1900	1901
1902	1903	.....	**1904**	1905	1906	1907
.....	**1908**	1909	1910	1911	.....	**1912**
1913	1914	1915	.....	**1916**	1917	1918
1919	.....	**1920**	1921	1922	1923	.....
1924	1925	1926	1927	.....	**1928**	1929
1930	1931	.....	**1932**	1933	1934	1935
.....	**1936**	1937	1938	1939	.....	**1940**
Ja **3**^{2}	Ja **4**^{3}	Ja **5**^{4}	Ja **6**^{5}	Ja **7**^{6}	Ja **1**^{7}	Ja **2**^{1}
Fe **6**^{5}	Fe **7**^{6}	Fe **1**^{7}	Fe **2**^{1}	Fe **3**^{2}	Fe **4**^{3}	Fe **5**^{4}
Ma **6**	Ma **7**	Ma **1**	Ma **2**	Ma **3**	Ma **4**	Ma **5**
Ap **2**	Ap **3**	Ap **4**	Ap **5**	Ap **6**	Ap **7**	Ap **1**
My **4**	My **5**	My **6**	My **7**	My **1**	My **2**	My 3
Ju **7**	Ju **1**	Ju **2**	Ju **3**	Ju **4**	Ju **5**	Ju **6**
Jy **2**	Jy **3**	Jy **4**	Jy **5**	Jy **6**	Jy **7**	Jy **1**
Au **5**	Au **6**	Au **7**	Au **1**	Au **2**	Au **3**	Au **4**
Se **1**	Se **2**	Se **3**	Se **4**	Se **5**	Se **6**	Se **7**
Oc **3**	Oc **4**	Oc **5**	Oc **6**	Oc **7**	Oc **1**	Oc **2**
No **6**	No **7**	No **1**	No **2**	No **3**	No **4**	No **5**

1st Clndr	2nd Clndr	3rd Clndr	4th Clndr	5th Clndr	6th Clndr	7th Clndr
1 Mo	1 Tu	1 We	1 Th	1 Fr	1 Sa	1 **Su**
2 Tu	2 We	2 Th	2 Fr	2 Sa	2 **Su**	2 Mo
3 We	3 Th	3 Fr	3 Sa	3 **Su**	3 Mo	3 Tu
4 Th	4 Fr	4 Sa	4 **Su**	4 Mo	4 Tu	4 We
5 Fr	5 Sa	5 **Su**	5 Mo	5 Tu	5 We	5 Th
6 Sa	6 **Su**	6 Mo	6 Tu	6 We	6 Th	6 Fr
7 **Su**	7 Mo	7 Tu	7 We	7 Tu	7 Fr	7 Sa
8 Mo	8 Tu	8 We	8 Th	8 Fr	8 Sa	8 **Su**
9 Tu	9 We	9 Th	9 Fr	9 Sa	9 **Su**	9 Mo
10 We	10 Th	10 Fr	10 Sa	10 **Su**	10 Mo	10 Tu
11 Th	11 Fr	11 Sa	11 **Su**	11 Mo	11 Tu	11 We
12 Fr	12 Sa	12 **Su**	12 Mo	12 Tu	12 We	12 Th
13 Sa	13 **Su**	13 Mo	13 Tu	13 We	13 Th	13 Fr
14 **Su**	14 Mo	14 Tu	14 We	14 Th	14 Fr	14 Sa
15 Mo	15 Tu	15 We	15 Th	15 Fr	15 Sa	15 **Su**
16 Tu	16 We	16 Th	16 Fr	16 Sa	16 **Su**	16 Mo
17 We	17 Th	17 Fr	17 Sa	17 **Su**	17 Mo	17 Tu
18 Th	18 Fr	18 Sa	18 **Su**	18 Mo	18 Tu	18 We
19 Fr	19 Sa	19 **Su**	19 Mo	19 Tu	19 We	19 Th
20 Sa	20 **Su**	20 Mo	20 Tu	20 We	20 Th	20 Fr
21 **Su**	21 Mo	21 Tu	21 We	21 Th	21 Fr	21 Sa
22 Mo	22 Tu	22 We	22 Th	22 Fr	22 Sa	22 **Su**
23 Tu	23 We	23 Th	23 Fr	23 Sa	23 **Su**	23 Mo
24 We	24 Th	24 Fr	24 Sa	24 **Su**	24 Mo	24 Tu
25 Th	25 Fr	25 Sa	25 **Su**	25 Mo	25 Tu	25 We
26 Fr	26 Sa	26 **Su**	26 Mo	26 Tu	26 We	26 Th
27 Sa	27 **Su**	27 Mo	27 Tu	27 We	27 Th	27 Fr
28 **Su**	28 Mo	28 Tu	28 We	28 Th	28 Fr	28 Sa
29 Mo	29 Tu	29 We	29 Th	29 Fr	29 Sa	29 **Su**
30 Tu	30 We	30 Th	30 Fr	30 Sa	30 **Su**	30 Mo

For Finding the Day of the Week for Any Date from 1800 to 1940.

To find the right Calendar—for July 1876, for instance; **look for 1876, run down that column to July, the figure 6 there refers to the 6th Calendar,** which shows that the 1st of July 1876 occurred on Saturday; the 4th on Tuesday, &c.

Note—In **Leap Years,** use the **small** figures for **Jan.** and **Feb.**

For any Date in the 18th Century, shift **two** days forward; and for the 20th, **two** days backward from the corresponding Day in the 19th. Thus, we find that in 1876, **July 4,** occurred on Tues.; hence. in **1776,** it must have occurred on Thurs.—**two** days forward from Tues.; and in **1976,** it will fall on Sun.—**two** days backward from Tues. (Art. 360.)

It is quite interesting to know on what Day births, deaths and other notable events occurred.

On what Day were **You** born?

The **Table** on the right shows on what Day of the month, in Mar., or Apr., **Easter Sundays** fall from the year 1801 to 1950.

The Council of Nice, in A. D., 325, decreed that Easter should be celebrated. always on the first Sunday after the Full Moon next after the Spring Equinox. Hence, Easter can come as early as March 22, as in 1818; and as late as April 25, as in 1886.

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EASTER SUNDAYS

1801	A 5	1851	A 20	1901	A 7
1802	A 18	1852	A 11	1902	M30
1803	A 10	1853	M27	1903	A 12
1804	A 1	1854	A 16	1904	A 3
1805	A 14	1855	A 8	1905	A 23
1806	A 6	1856	M23	1906	A 15
1807	M29	1857	A 12	1907	M31
1808	A 17	1858	A 4	1908	A 19
1809	A 2	1859	A 24	1909	A 11
1810	A 22	1860	A 8	1910	M27
1811	A 14	1861	M31	1911	A 16
1812	M29	1862	A 20	1912	A 7
1813	A 18	1863	A 5	1913	M23
1814	A 10	1864	M27	1914	A 12
1815	M26	1865	A 16	1915	A 4
1816	A 14	1866	A 1	1916	A 23
1817	A 6	1867	A 21	1917	A 8
1818	M22	1868	A 12	1918	M31
1819	A 11	1869	M28	1919	A 20
1820	A 2	1870	A 17	1920	A 4
1821	A 22	1871	A 9	1921	M27
1822	A 7	1872	M31	1922	A 16
1823	M30	1873	A 13	1923	A 1
1824	A 18	1874	A 5	1924	A 20
1825	A 3	1875	M28	1925	A 12
1826	M26	1876	A 16	1926	A 4
1827	A 15	1877	A 1	1927	A 17
1828	A 6	1878	A 21	1928	A 8
1829	A 19	1879	A 13	1929	M31
1830	A 11	1880	M28	1930	A 20
1831	A 3	1881	A 17	1931	A 6
1832	A 22	1882	A 9	1932	M27
1833	A 7	1883	M25	1933	A 16
1834	M30	1884	A 13	1934	A 1
1835	A 19	1885	A 5	1935	A 21
1836	A 3	1886	A 25	1936	A 12
1837	M26	1887	A 10	1937	M28
1838	A 15	1888	A 1	1938	A 17
1839	M31	1889	A 21	1939	A 9
1840	A 19	1890	A 6	1940	M24
1841	A 11	1891	M29	1941	A 13
1842	M27	1892	A 17	1942	A 6
1843	A 16	1893	A 2	1943	A 25
1844	A 7	1894	M25	1944	A 9
1845	M23	1895	A 14	1945	A 1
1845	A 12	1896	A 5	1946	A 21
1847	A 4	1897	A 18	1947	A 6
1848	A 23	1898	A 10	1948	M28
1849	A 8	1899	A 2	1949	A 17

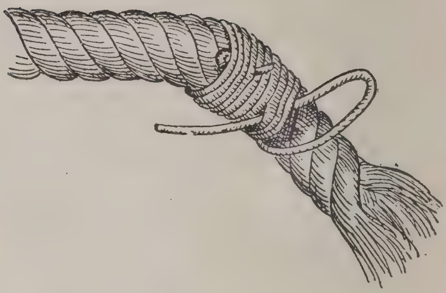
All Kinds of Knots and Bends Useful to Plumbers and Other Mechanics

Many plumbers, steam fitters, hoisting engineers, and other mechanics have asked me why I do not have an article in my book with illustrations on tying knots. Realizing that the knowledge of tying a reliable knot one that will not slip or loosen and one that can be easily untied, is of great value to almost all mechanics, I have added this subiect to my book.

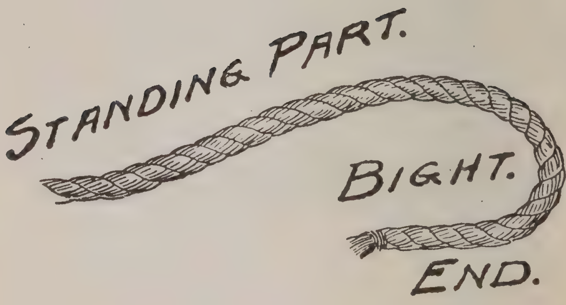
When handling and tying ropes the following terms are used: "Standing Part," "Bight" and "End." The "Standing Part" is the long part of the rope; the "Bight" is the curved part or loop, formed while working or handling; the "End" is that part used in forming the knot or hitch. Before commencing work, the loose ends or strands of a rope should be "whipped" or "seized" to prevent the rope from unraveling. An expert can tie a knot, make a splice, etc., without whipping, but we advise whipping the end before manipulating the rope.

To whip a rope, take a piece of twine or string, lay it on the rope an inch or two from the end, pass the twine several times around the rope, keeping the ends of the twine under the first few turns to hold it in place; then make a large loop with the free end; bring it back to the rope and continue winding for three or four turns around both the rope and end of twine; and finish by drawing the loop tight by pulling on the free end, as shown in Figure AA. Figure BB shows the "Standing Part," "Bight" and "End."

AA



BB


STANDING PART.
BIGHT.
END.

Nooses, Loops and Mooring Knots

On the following pages I give illustrations of a number of nooses, loops, mooring knots, and hitches, such as used by sailors. It always astonishes an onlooker (landsman) who is a careful observer, to see the easy manner in which a sailor handles heavy dripping hawsers or cables, and, with a few turns, makes them fast to pier-head or spile, so that although a tremendous pull is exerted, there is not the slightest give or slip to the rope. Yet, a moment later, with a few quick motions, the line is cast off, tightened up or paid out, as may be the case.

Figure "A" and Figure "B" show "Cleat" and "Wharf-Ties." A few turns under or over and around a cleat or two spiles is a method well understood and used by sailors.

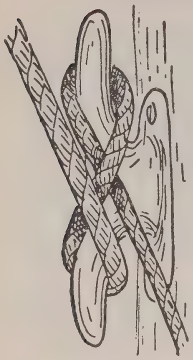
Figures "C" and "D" show "Bow-Line on Bight" and "Running Bow-Line." The "Bow-Line on Bight," Figure "C," is easily made and is very useful in slinging casks and barrels and in forming a seat for men to be lowered or hoisted from buildings or ships when painting or cleaning.

Figure "D," the "Running Bow-Line," is merely a bow-line with the ends passed through the loop, forming a slip-knot.

"Waterman's Knot," Figure "E," is often used, with a man holding the free end, for in this way a slight pull holds the knot fast, while a little slack gives the knot a chance to slip without giving away entirely and without exerting any appreciable pull on the man holding the end.

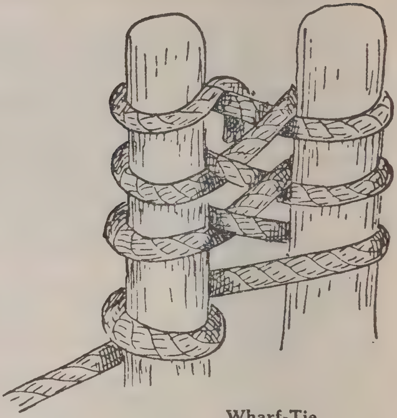
"Lark's Heads" are also used in conjunction with a running noose and is shown in Figure "F."

Fig. A



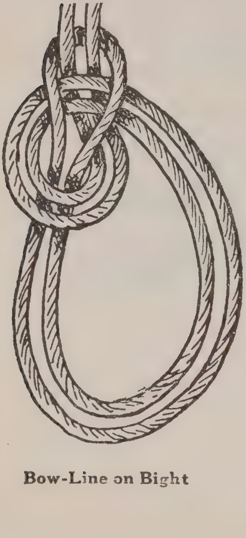
Cleat

Fig. B



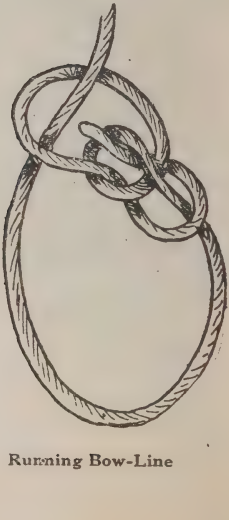
Wharf-Tie

Fig. C



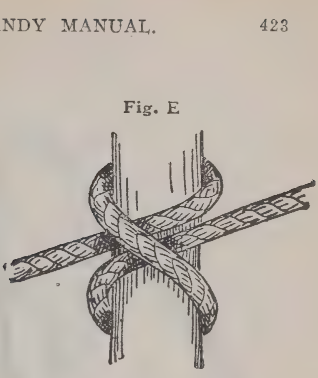
Bow-Line on Bight

Fig. D



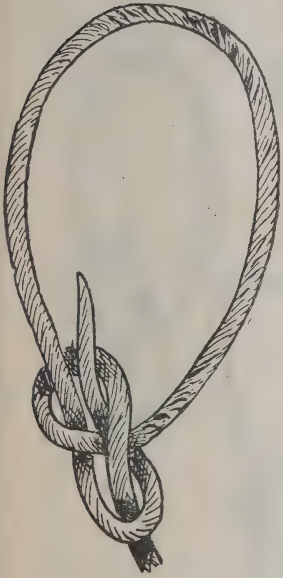
Running Bow-Line

Fig. E



Waterman's Knot

Fig. G



Bow-Line

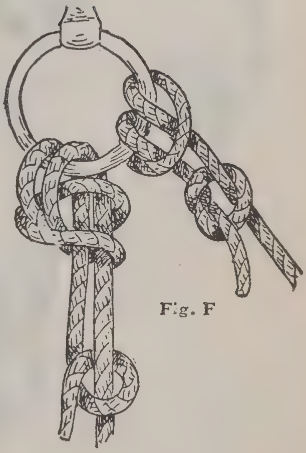


Fig. F

Lark's Head and Running Noose

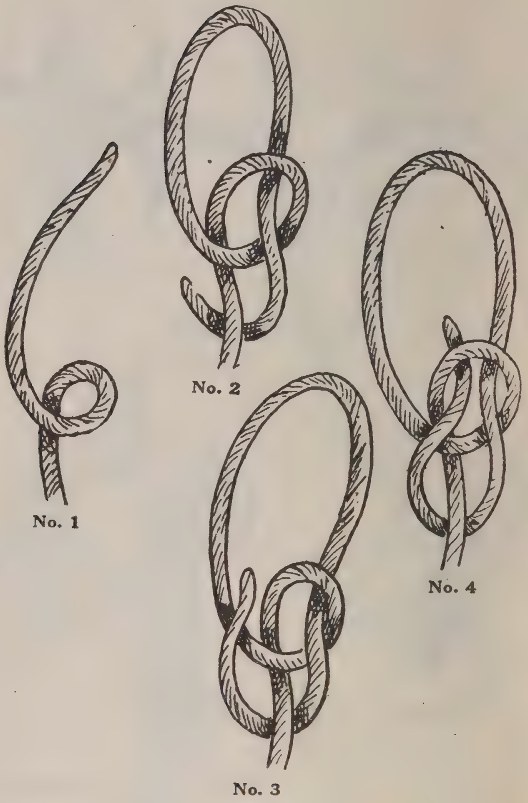

No. 1
No. 2
No. 4
No. 3

Fig. G

The Bow-Line Knot

The Bow-Line Knot

(See Page 424)

The "Bow-Line" knot is by far the best knot and is used very much by sailors. It is a true knot, never slips, jams, or fails; is easily and quickly untied and is useful whenever a knot has to be tied. The knot completed is shown in Figure "G" No. 5 and in its various stages in No. 1, 2, 3 and 4. In No. 1 the rope is shown with a bight or cuckold's neck formed with the end over the standing part. Pass 1 back through the bight, under, then over, then under, as shown in 2, then over and down through the bight, as shown in 3 and 4, and draw taut, as in 5.

The Tomfool or Handcuff Knot, Etc.

(See Page 426)

Other loops are made, as shown in Figures "H," "I," "J" and "K," but they are not as safe and useful as the "Bow-Line," Figure "G."

Figure "L," known as the "Tomfool Knot," or "Handcuff Knot," is made like a running knot, Figure "H." The firm end is passed through the open, simple knot so as to form a double loop or bow. If the hands or wrists are placed within these loops and the latter drawn taut, and the loose ends tied firmly around the central part, a pair of secure handcuffs will be the result.

Lark's Head Knot

(See Page 427)

Knots used in securing a rope to an object are known as "hitches" or "ties." Figure "M" shows one of these, called "Lark's Head." To make this hitch, pass a bight of the rope through the ring, or other object to which you intend to hitch, and then pass a marline-spike, piece of round iron, pipe, or piece of wood, if you have nothing else at hand, as shown at "A." The end of the rope is then laid over and under the standing part and back over itself. This knot is instantly released by withdrawing the piece "A." Figure "N" shows the toggle with "A" withdrawn.

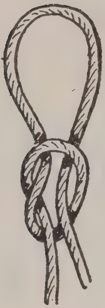


Fig. H

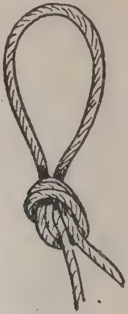


Fig. I

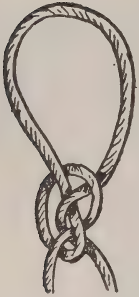


Fig. J

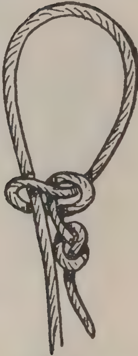


Fig. K

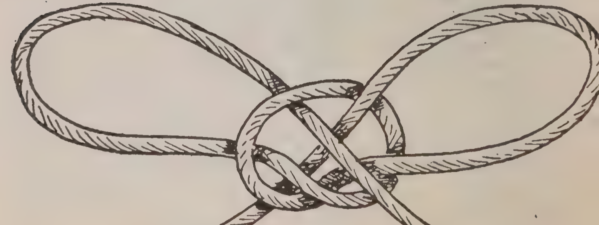


Fig. L

Fig. M

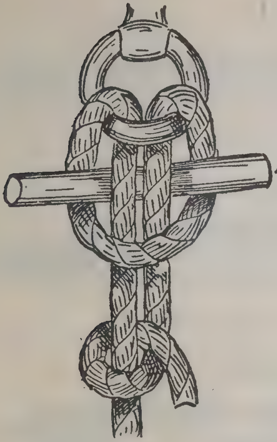
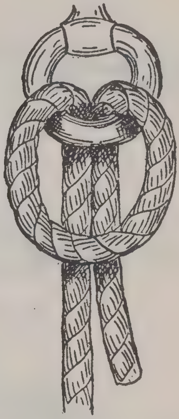
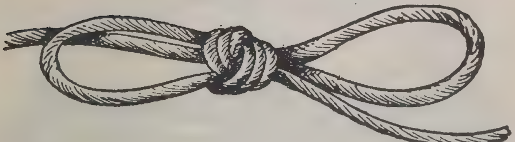


Fig. N



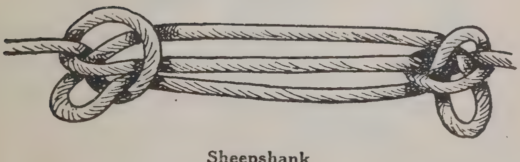
Lark's Head

Fig. R



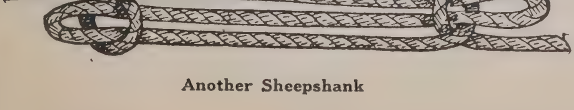
Bow Shortening

Fig. S



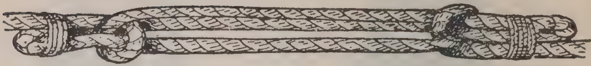
Sheepshank

Fig. T



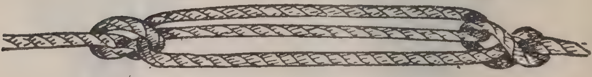
Another Sheepshank

Fig. U



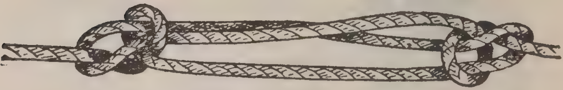
Sheepshank with Ends Seized

Fig. V



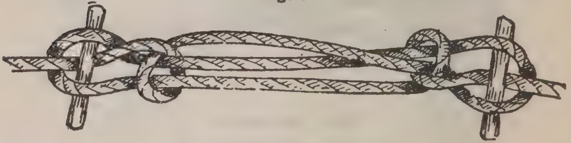
Sheepshank for Free-ended Rope

Fig. W



Sheepshank for Free-ended Rope

Fig. X

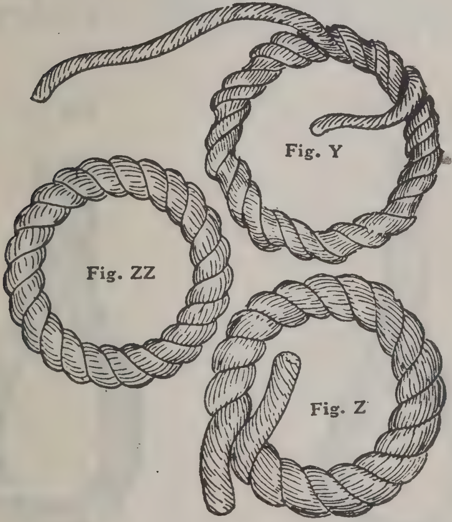


Sheepshank with Toggle

Figure "R" is a very simple shortening and needs no description. It will not withstand a very great strain, but is secure from untying by accident, and is very useful taking up spare rope of lashings on bundles or baggage.

"Sheepshank" or "Dogshank" are also used for shortening ropes, especially where both ends are fast, as they can be made in the center of the rope, although the rope is fast at both ends. The best and most secure form is shown in Figure "S." A simple running knot is first made; a bend is pushed through the loop, which is then drawn taut; the other end of the bend is fastened in the same manner and the shortening is complete. A simpler form is shown in Figure "T," but this can hardly be depended upon unless the ends are seized, as shown in Figure "U."

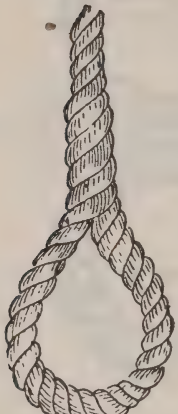
Figures "V" and "W" show two other kinds of shortenings, but these can only be used when ends of the rope are free, and are intended for more permanent fastenings than the ordinary Sheepshank. Figure "X" is particularly adapted to be cast loose at a moment's notice by jerking out the toggles.



Grommets

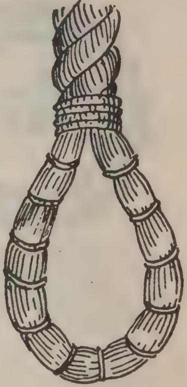
Grommets are round, endless rings of rope, useful in many ways, often used as handles for chests, for rings to lengthen ropes, etc. A grommet is formed of a single strand of rope **five times as long as the circumference of the grommet when complete.** Take the strand and lay one end across the other at the size of loop required, and with the long end follow the "grooves" or "lay" of the strand until back to where you started, Figure "Y," thus forming a two stranded ring. Then continue twisting the free end between the turns already made until the three-stranded ring is complete, Figure "Z." Now finish and secure the ends by making overhead knots, pass the end under the nearest strand and trim off ends close, Figure "ZZ." If care is taken and you remember to keep a strong twist on the strand while "laying up" the grommet, the finished ring will be as firm and smooth and endless as the original rope.

Fig. BB



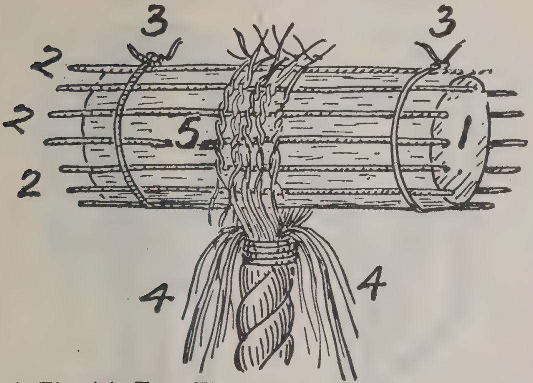
Artificial Eye

Fig. AA



Flemish Eye

Fig. AA1



A Flemish Eye, Figure AA, is an eye made in a manner as described below, and shown in process of making in cut, Figure AA1. Take a piece of wood, the size of the intended eye "1." Around this wood lay a number of pieces of yarn or marline, 2.2.2., and fasten them by tying with twine "3" and "3." Whip the piece of rope which eye is to be formed and unravel and open out the strand as at "4." Lap the yarn over the wood and the stops "5," and fasten together by overhand knots "5," worm the free ends under and over and then bring up the ends of the stops "2" and tie around the strands of eye, as shown. The eye may be finished neatly by whipping all around with yarn or marline, and will then appear as in Figure AA.

An artificial Eye, Figure BB, is still another form of eye, which will be found useful, and easier and quicker to make. It is also stronger. Take the ends of a rope and unlay one strand; place the two remaining strands back alongside of the standing part, Figure CC. Pass the loose strand, which has been unlaid, over the end, and follow around the spaces between the two strands and then around the eye,—as in making a grommet,—until it returns down the standing part and lies under the eye, with the strands, Figure DD. Then divide the strands, taper them down, and whip the whole with marline or yarn, Figure EE.

Another eye which at times is useful is the "Throat Seizing" shown in Figure FF. This is made by opening the end slightly and lashing it to the standing part, as shown.

Fig. CC

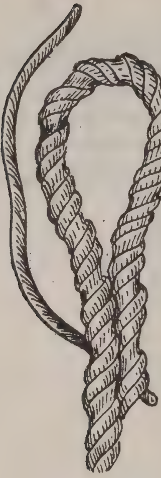


Fig. DD

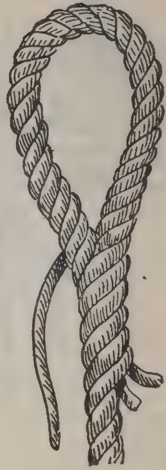


Fig. EE

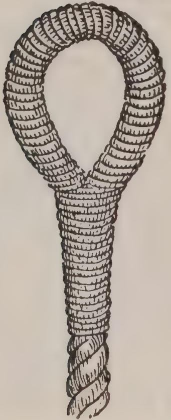


Fig. FF

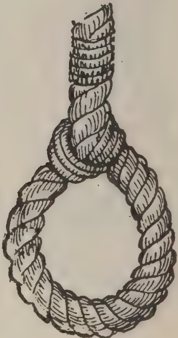
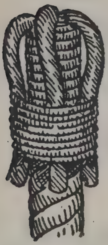
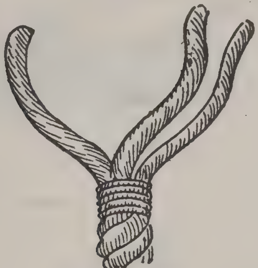


Fig. GG



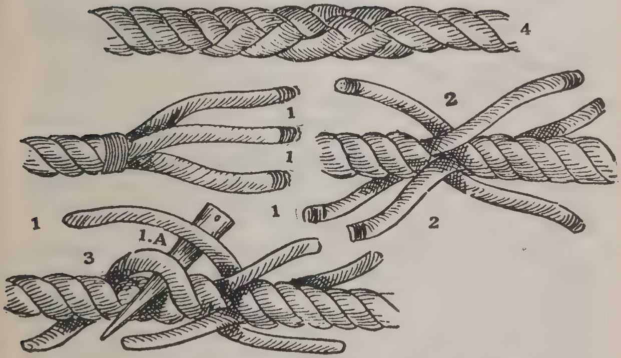
Ending Rope

Fig. HH



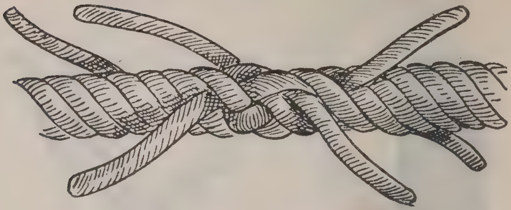
Ending Rope

Fig. II

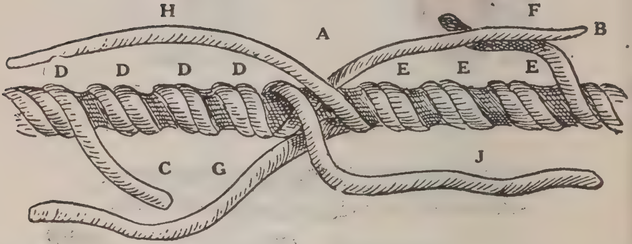

4
1
1
2
1
1
2
1.A
3

Short Splice

Fig. JJ



Short Splice



Long Splice
Fig. KK

A simple way of finishing the end of a rope is to seize the end, as shown in Figure GG, and open out the strands, bring the strands back alongside the rope, and whip the whole. (Figure HH).

Splicing is much better than tying or bending ropes together. A good splice always looks better than a knot. A man familiar with splicing will make a splice almost as quickly as the ordinary man can tie a secure knot. In many cases where a rope must pass through sheaves or blocks a splice is absolutely necessary to fasten the ends of two ropes or two parts of parted rope together.

The simplest of all splices is called the "Short Splice," Figure II. This is made as follows: Untwist the ends of rope for a few inches and seize with twine to prevent any more unwinding, as shown; also seize the end of each strand to prevent unraveling and grease or wax the ends until smooth and even. Now place the two ends of the ropes together, as shown, Figure JJ. Then with a marlin spike, or pointed stick, work open the strand, 1.A, and through this pass the strand No. 1 of the other rope; then open strand No. 3 and pass the next strand of the other rope through it, and then the same way with the third strand. Next, open the strands of the other rope, below the seizing, and pass the strands of the first rope through as before, No. 1 and No. 2. The ropes will now appear as in No. 4. Now untwist the six strands and cut away about half of the yarns from each and seize the ends as before. Pass these reduced strands through under the whole strands of the rope,—the strands of the left under the strands of the right rope, and vice versa,—for two or three lays, and then cut off projecting ends, after drawing all as tight as possible.

If an extra neat splice is desired, the strands should be gradually tapered as you proceed, and in this way a splice but little larger than the original size of the rope will result. The only difficulty that may be found in making this splice is in getting the strands to come together in such a way that two strands will not run under the same strand of the opposite rope. To avoid this, remember that the FIRST STRAND MUST BE PASSED OVER THE STRAND WHICH IS FIRST NEXT TO IT AND THROUGH UNDER THE SECOND AND OUT BETWEEN THE SECOND AND THIRD. In the following operations the strands are passed OVER the third and UNDER the fourth; the figures will make this clear.

A very much better and stronger splice is the "Long Splice," which will run through any block that will admit the rope itself. A well-made long splice can not be noticed on the rope after a few days use. To make this splice, unlay the ends of the rope about four or five times as much as for short splice, or from four to five feet; unlay one strand in each rope half as much again; place the middle strands together as at A. Then the additional strands will appear as at B and C, and the spiral groove, left where they were unlaid, will appear as at D and E. Take off the two central strands, F and G, and lay them into grooves D and

E, until they meet at B and C; and be sure to keep them tightly twisted. Then take strands H and J, cut out half the yarn in each, make an overhand knot in them, and tuck the ends under the next lays as in short splice. Do the same with strands B and C and F. and G, dividing, knotting and sticking the divided strands in the same way. Finally, stretch the rope tight, pull and pound and roll the splice until smooth and trim off all loose ends close to the rope.

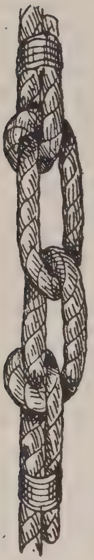
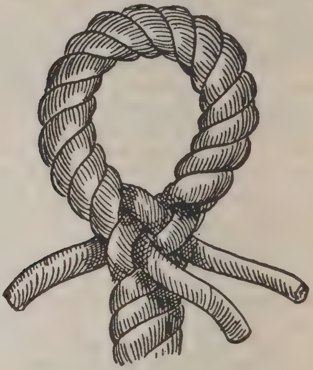
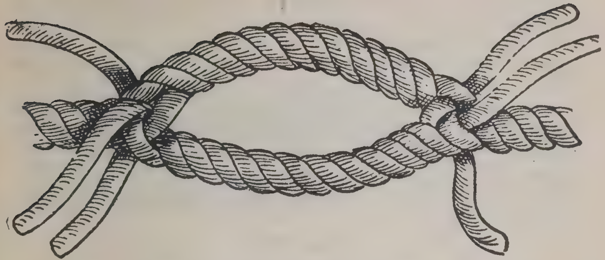


Fig. LL



An "Eye Splice," Figure LL, is easy to make and is useful in many ways. It is made in the same way as a short splice, but instead of splicing the two ends together, the end of the rope is unlaid and then bent around and spliced into its own strands of the standing part, as shown in the illustration.

Fig. MM



A "Cut Splice," Figure MM, is made just as eye splice or short splice is made, but instead of splicing two ropes together, end to end, or splicing an end into a standing part, the ends are lapped and each is spliced into the standing part of the other, thus forming a loop or eye in the center of the rope.

Fig. NN

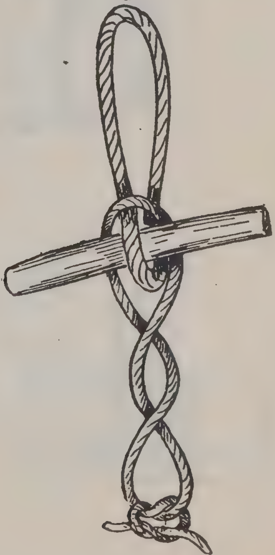
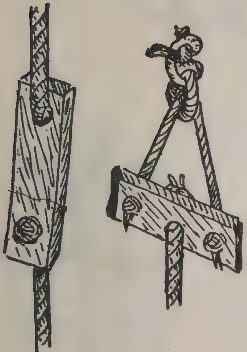


Fig. OO



When a person has acquired the knowledge of making knots, ties, bends, hitches, and splices, he will find the usefulness of ropes in many ways. Barrels, casks, bales, timbers, bundles of pipes, and other objects can be securely roped or slung. A buckle may be formed as shown in Figure NN. If a swivel is required it can be arranged as shown in Figure OO. Several simple slings are shown in Figure PP.

Fig. PP

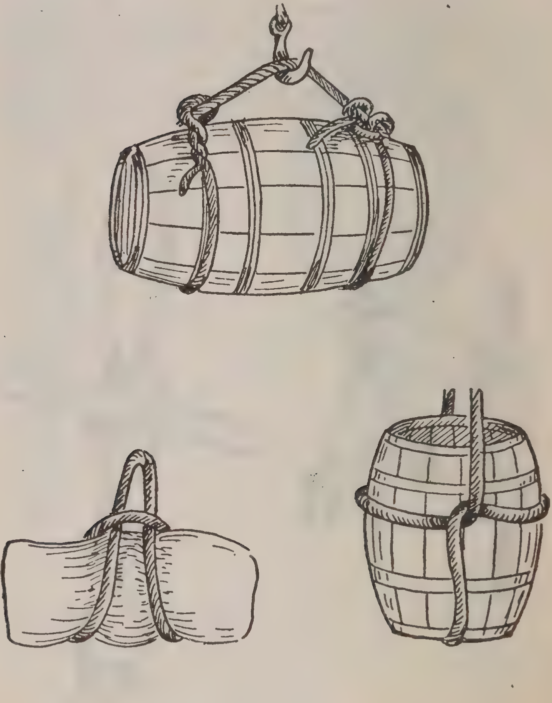


Fig. RR

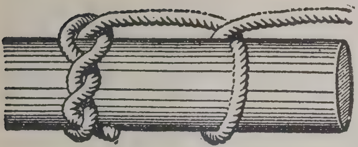
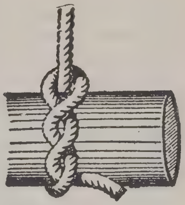


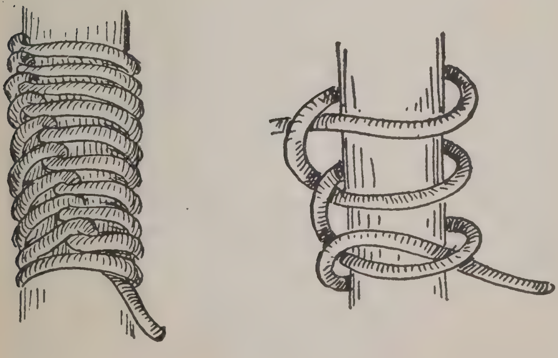
Fig. SS



These Hitches are Handy for a Mechanic

Figure RR is called "Timber Hitch" and Figure SS is a "Timber and Half Hitch." Both are much used by sailors and mechanics, such as plumbers, steam fitters and gas fitters, when hoisting pipes and other materials. If, however, pipes and other materials or fixtures are required to be hoisted in a horizontal position, the "sling" is best.

Fig. QQ



Half Hitchwork

To prevent a rope from unraveling at the ends, the ends are treated in several ways. Half hitchwork, as shown in Figure QQ, is a very simple way and is often used for doing this, and is done as follows: Take a half hitch around the rope to be served, then another below it; draw tight; take another half hitch, and so on until the object is served and a series of half hitch knots form a special twist, as shown in illustrations.

There are endless occasions where the half hitch knot can be used. Ropes, a spliced piece of wood such as a hammer handle, bottles, jugs, and many other articles can be covered with half hitch knots.

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